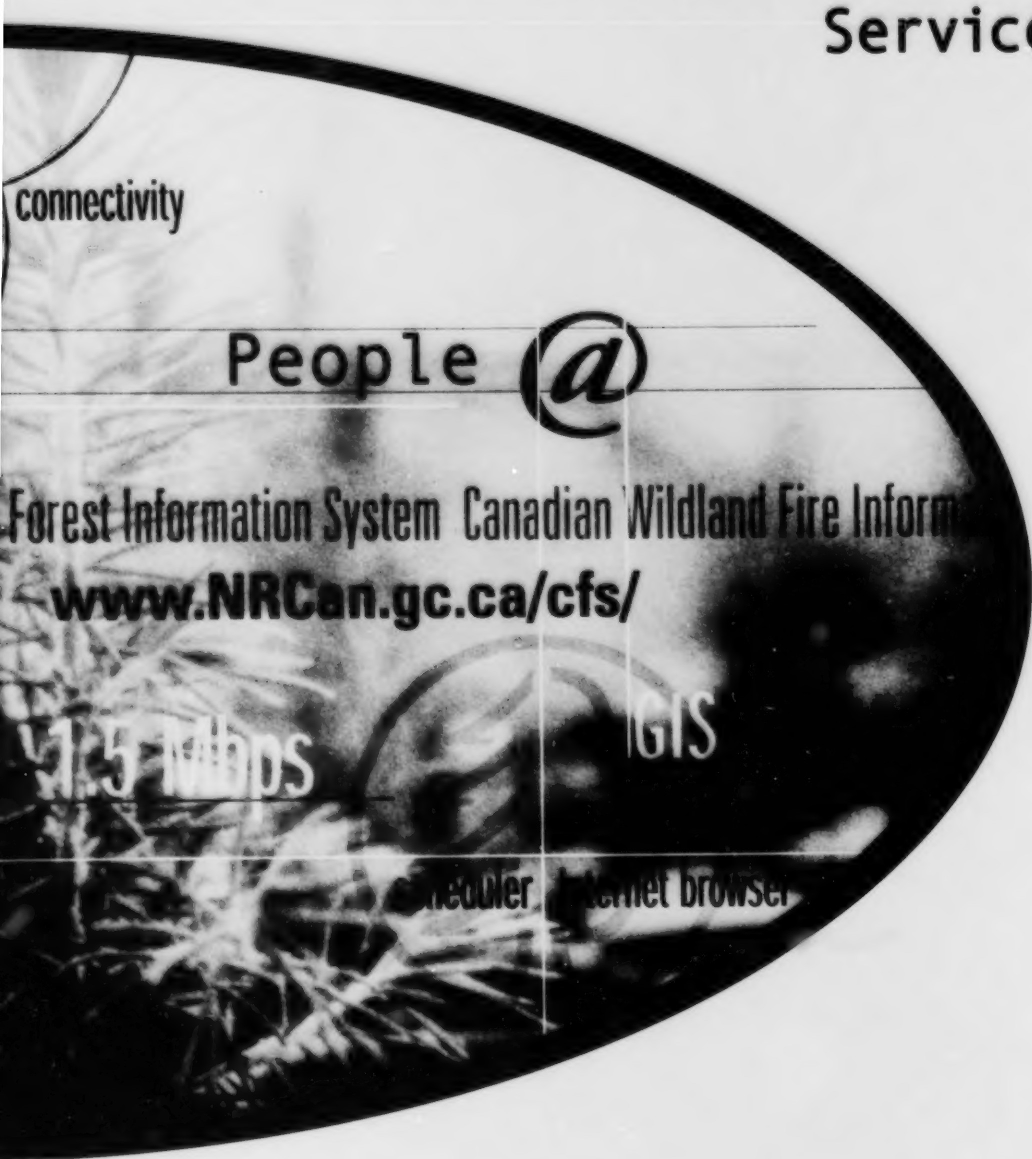
Managing Knowledge at the Canadian Forest Service



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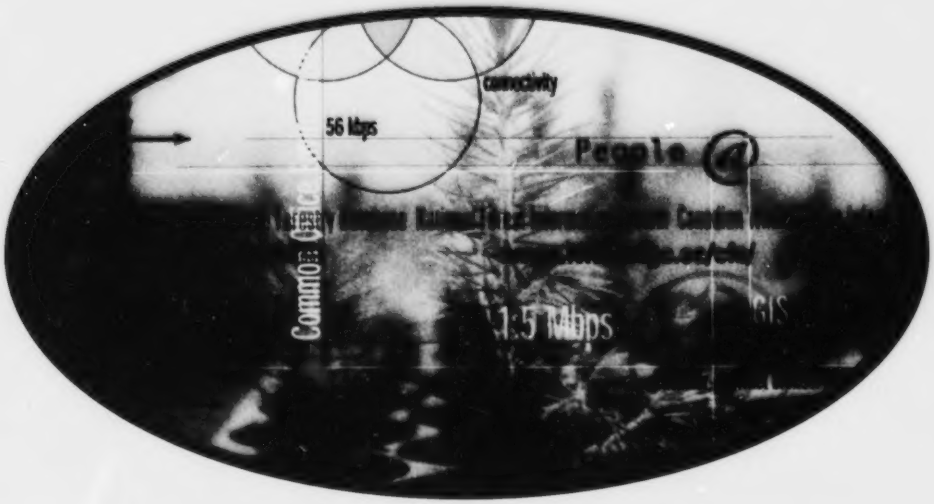

A new information revolution is well under way... It is not a revolution in technology, machinery, techniques, software, or speed. It is a revolution in CONCEPTS.

—Peter Drucker, *Management Challenges for the 21st Century* (1999)

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Preface

Researching and writing *Managing Knowledge at the Canadian Forest Service* was an opportunity to review the rapidly expanding literature on knowledge management in order to teach myself about it and to explain it to others; to integrate current thinking on its many aspects into one document; and to propose some new models of knowledge management. The main lesson that I learned during the process was that knowledge management is a field still in its infancy; many of its concepts are not yet well defined and understanding will only come after much more discussion. Those who are willing to venture into this major new field will have the opportunity to shape its direction.

Although the examples given in this publication are specific to the Canadian Forest Service (CFS), a sector of Natural Resources Canada, the models and framework are generic. For example, they have already been adapted for departmental use with relatively little modification. They were also applied to a Global Disaster Information Network initiative. In the latter case, extensions were developed that have been incorporated into the original CFS models and framework and are presented here. I urge you to visualize how the models and frameworks might be used in other domains. I believe they could form some part of most knowledge infrastructures.

This publication is mainly intended for managers, scientists, and information specialists. Because I have tried to provide a nonspecialized audience with an introduction and some background to this emerging discipline, many technical details have been omitted. The discussion of terminology (including a glossary) near the end of the publication is meant to help orient readers.

Although I present some new ways of looking at knowledge management, I am greatly indebted to the thinking of many people. I admit that it sometimes became difficult to distinguish my thoughts from those of others that I had read somewhere, sometime, but had not necessarily recorded. To the extent that I expropriated ideas without proper acknowledgment, I apologize to their originators.

I owe a similar debt to the many people who reviewed and commented on various aspects of this material, and in particular to members of the CFS Knowledge Infrastructure Steering Committee. Although there is a resemblance between what they read and my original concepts, there is also much that differs—for the better.

I close with a special note of gratitude to Catherine Carmody, a science editor at CFS in Ottawa, whose considerable patience in making fuzzy writing more precise, identifying inconsistencies, and methodically fixing the inevitable loose ends, made this document eminently more readable and understandable. A heartfelt thanks is also due to Sandra Bernier for graphic design and layout as well as to Denis Rochon for editing la version française.

In the final analysis, however, all errors of omission or commission are my responsibility alone; may they be few in number. If, after reading these pages, you know something about knowledge management that you did not know before and if you sense some of the excitement of the knowledge revolution's opportunities and challenges, I will have accomplished my purpose.

Introduction

> *Gottlieb Daimler and Ransom Olds, and their friends and rivals thought they had improved the horse. They had no way of knowing that the automobile would fill the countryside with suburbs—which, in turn, created thousands of jobs building roads and houses, making lawn mowers, selling tulip bulbs, and delivering pizza.*
>
> —Thomas Stewart, *Intellectual Capital* (1997)

The world is undergoing a fundamental socioeconomic change from an industrial society to an information society and knowledge-based economy. Societies, economies, and organizations that do not adapt to these changes will become increasingly marginalized. Although a revolution in information and communication technologies is well under way, we seem to be drowning in information but starving for knowledge. In an era of increasing complexity and responsibilities, traditional methods of synthesizing and disseminating knowledge are no longer adequate.

The Canadian Forest Service (CFS), Natural Resources Canada, recognized the pressing need to adapt to the new order. It saw that it needed to better manage its data, information, and knowledge assets, support the synthesis of new knowledge, and facilitate access to CFS knowledge holdings. In May 1997, the CFS established a steering committee to create a framework for developing and implementing a knowledge infrastructure.

The purpose of the infrastructure is to develop and use rapidly evolving information and communications technologies to

- Create a rich, publicly accessible national database of technical, scientific, and economic information about Canada's forests.
- Promote the competitiveness of Canada's forest sector in the knowledge economy.
- Facilitate informed public participation and diversity of inputs in developing and implementing sustainable forest management in Canada.
- Address the increasing complexity and multidimensional nature of forest management and land-use decision-making.
- Support Canada's international commitments on forest stewardship.

Managing Knowledge at the Canadian Forest Service provides a foundation on which a knowledge infrastructure can be built and an initiative put forward. It is divided into three parts. The first part describes the technological, social, forestry, and organizational context that surrounds knowledge management at the CFS. The second part develops a model of knowledge management and concludes with a proposed three-dimensional framework for a CFS knowledge infrastructure. The third part addresses the establishment of a CFS knowledge initiative and presents an overview and a discussion for the development of a strategic plan.

Part 1 Context for Knowledge Management

> *One tragedy of the human condition is that each of us lives and dies with little hint of even the most profound transformations of our society and our species that play themselves out in some small part through our own existence.*
>
> —James A. Beniger, *The Control Revolution* (1986)

The discussion of context is divided into four sections that focus the reader's attention from the general to the specific. Part 1 begins with a review of the technology underlying and enabling the management of knowledge. The concepts of the information society and knowledge economy are interpreted according to how, at an institutional level, they influence knowledge management. This is followed by an examination of the nature and characteristics of forestry knowledge. The discussion of context concludes with an overview of the CFS organizational structure, within which the knowledge infrastructure will be developed.

Technology

Technological change occurs in a combination of continuous small incremental changes, discontinuous radical inventions, and occasional massive shifts in some pervasive technology.

—Richard Lipsey, *Economic Growth, Technological Change, and Canadian Economic Policy* (1996)

Knowledge infrastructure is founded on an emerging synthesis of four rapidly advancing areas of technology: computers, electronic communication, information management, and computer networks. The confluence of these interdependent technologies provides unprecedented global-scale opportunities to exchange, integrate, and use information in virtually every facet of social and economic activity. To understand where we are and why this is important, we must first review how we got here.

Current theories of evolution suggest that Darwin was partially right. Although there is much evidence of gradual speciation, the rate of change is too slow to have produced the myriad of life forms that we see today. This realization has led to the theory of "punctuated equilibrium"—gradual evolution punctuated with occasional major "jump-shifts." Kuhn (1970) showed that science advances with similar discontinuities. The emerging science of complexity suggests that most, if not all, large, complex systems exhibit similar behavior (Waldrop 1992). Evidence ranges from the growth and collapse of empires and stock markets to self-ordering in biological systems and the universe.

General Purpose Technologies

The concept of punctuated equilibrium was applied to technological evolution (Lipsey 1996). He refers to the jump-shifts as "general purpose technologies" (GPT). There have been perhaps a dozen such technologies that have resulted in "deep structural adjustments" to existing infrastructure, economies, and social order. Four general-purpose technologies have set the stage for the current information and communication technology (ICT) revolution: writing, printing, electricity, and computers.

Writing

In the earliest civilizations, records were retained in memory or simple counting devices. Writing was first developed around 3000 BC in Mesopotamia; several thousand years later it was developed independently in China, and later still, by the Maya in Central America. Writing transformed society by enabling taxation and record keeping. These made it possible to finance large public projects, such as irrigation, which turned deserts into fertile crop land. This permitted the development of cities, specialized trades, and higher standards of living. Like most general-purpose technologies, writing was not a single creative act of genius, but a gradual evolution from simple counting systems. It can be traced back to the Neolithic agricultural revolution and the abstract expression of numbers and symbols to represent words and sounds.

Printing

Before printing, manuscripts were laboriously and expensively reproduced by hand at a rate of about 1200 pages per monk per year (Drucker1999). Within a few decades of the invention of movable type, books

could be produced at a rate of 250 000 pages per person per year. The cost of producing books dropped correspondingly and one of the largest "industries" of the Middle Ages disappeared. This enabled mass communication, eliminated the monopoly of knowledge possessed by a limited elite, and eventually led to a great expansion of learning. A massive restructuring of the social fabric resulted, accompanied by considerable strife as vested interests resisted the changes. The Age of Discovery, the development of science, and the Reformation were founded upon the new capacity to rapidly and widely distribute new knowledge and ideas (Burke 1985). Printing spread most rapidly where established authority was weakest, such as in the Netherlands. There it resulted in a broadly educated society that developed multinational corporations, a stock exchange, a federal state, and a well-drilled army, which collectively led to a worldwide economic empire.

Electricity

The most pervasive technology ever developed to deliver energy is electricity. It enabled the development of the telegraph and for the first time in history information was transmitted faster than the speed of human travel. Development of an infrastructure for producing and transmitting electricity led to broad classes of new products and industries that dramatically altered the way we live. New classes of communication technologies were invented, including the telephone, radio, and television. Electricity also made possible a fundamental new technology—the computer.

Computers

At the end of World War II, the military, which was using computers to calculate the trajectory of artillery shells, estimated that five machines would satisfy the total civilian demand. Fifty years later the computer is seen as a GPT. Substitution of transistors for tubes, software for hard wiring, and higher-level programming languages greatly decreased the size and cost while increasing the power, flexibility, and range of applicability of computers. Mainframe computers gradually became the mainstay of scientific and business data processing. Super computers evolved to meet the growing demand for increased computing power.

Personal computers (PCs) were first viewed as a hobbyist's curiosity, until word processing and spreadsheet software made them indispensable to everyday business applications. The graphical user interface (GUI) helped to popularize PCs by making them easy to use. Today, every sector of the economy and of society is inextricably linked to the computer. A 1993 car incorporated more computer power under the hood than Neil Armstrong had in the lunar module (Tapscott and Caston 1993).

In 1965, Charles Moore, a cofounder of Intel, predicted that the capacity of computer chips would double every year (Gates 1995). Thirty years later, this remarkable foresight, now known to engineers as Moore's Law, continues to hold, with an 18-month doubling period. The law is expected to hold for another 20 years, resulting in a computing speed 10 000 times faster than today's. Equally important for general usability, the cost of computing has decreased similarly. Today's $2000 laptop contains more power than a $10 million IBM mainframe of two decades ago.

Electronic Communications

What distinguishes modern communications from previous periods is the orders-of-magnitude increase in transmission speed and capacity. These result primarily from the use of microprocessors and fiber optics. There are two primary branches of electronic communication—switching and transmission.

Switching

Switching is fundamental to communication networks. Without switching, every node would require a pair of wires connected to every other node, an astronomical number of combinations. With switching, one pair of wires connects each node to the switch, which connects to every other node in the net or to a gateway to other networks. Development of fiber optic cable required parallel development of switches to process optical signals.

Two basic switching methods are used, circuit switching and packet switching. Circuit switching involves one-to-one contact as in a telephone call. Once connected, the line remains dedicated until either end hangs up. This is the most useful method for the continuous transfer of large amounts of data.

Packet switching is a key feature of Internet communication. Data is divided into segments, or packets, each with an associated header (routing information). Packet switches (computers) examine the header and move the packet to another site closer to its destination. The switches select alternative routes when a line is at capacity or fails. This allows a large number of messages

to share lines as each packet is only a small part of the total flow. The characteristic downloading of Web pages in bits and pieces arises from this switching method. Packet switching is totally dependent on computer technology.

Transmission

Transmission moves information from one place to another. Two basic transmission methods are used—connected and wireless. Both have a range of transmission rates with associated advantages and disadvantages.

Telephone lines, accessed through dial-up modems, provide basic connectivity to virtually any place in the world. Current modem transfer rates are 56 kbps (analog) and 128 kbps (digital). High-speed lines provide a thousand-fold increase—up to 45 Mbps, but at significantly higher cost and complexity. Such lines are normally installed by large organizations with high volumes of use (200+ person-hours per day). Optical fiber can currently deliver up to 155 Mbps. This technology is currently used primarily for broadband inter-network connectivity.

Radio can reliably transmit data at rates up to 56 kbps to a distance of 100 km. Although currently somewhat limited, this offers the prospect of extending Internet capability beyond the limit of wired connections at a relatively low cost. Microwave transmission links networks without wires. This is a cost-effective technology where microwave networks are in place. Satellite transponders receive signals transmitted from ground stations and rebroadcast them back to earth. Although this approach eliminates distance and line-of-sight restrictions, it is very expensive. The cost of this technology is a prime driver of the development of much less expensive broadband digital connectivity.

Information Management

During the past 40 years, information management has evolved through four generations of increasing sophistication in transforming data into knowledge.

Data processing

Electronic data processing was first applied by organizations to automate paperwork. Its functions included coding, entry, input, and storage. Processing focused on efficiently performing massive numbers of relatively simple operations. File organization was based on sequential, indexed, or direct access flat files. Output was typically in the form of computer printouts.

Database management

Database management systems were developed to manage multiple complex files. By separating data entry and file organization from application programs, changes could be made without reloading all the data and reprogramming every application. Hierarchical, network, and relational file structures support complex search and retrieval of data from multiple files. Security features control access and modifications of data. Such systems can typically rebuild a database lost as a result of hardware failure.

Information systems

Information systems transform data into information. They access data from multiple internal and external sources. This normally requires robust automated communication, data extraction, and quality control capabilities. Information systems manage multiple databases that archive operational data; support interactive queries and report generation; and produce easily understandable outputs tailored to the needs of the user. Specialized information systems have been adapted to many specific functions (production, accounting, inventory), domains (wildland fire, forest health, forest inventory), and organizational levels (operational, management, and executive).

Decision-support systems

Decision-support systems synthesize information into knowledge tailored to specific decisions. They may use sophisticated analysis techniques, process models, inference engines, and artificial intelligence processors. Decision-support systems are characterized by functional flexibility, wide adaptability, ease of use, and quick response. They present information in the form of key elements, but have "drill-down" capability for more detail as required. Award-winning examples of decision-support systems include ship acquisition by the US Coast Guard (Kimbrough et.al. 1990), automated extraction of information from sales data (Schmitz et. al. 1990), and wildfire disaster declarations (Simard and Eenigenburg 1990).

Computer Networks

The evolution of computer networks during the past three decades can be grouped into five major advances.

Each advance resulted in a corresponding significant increase in the flexibility, power, applicability, and usability of networks.

ARPANET

The Advanced Research Projects Agency Network (ARPANET) is considered to be the origin of the Internet. It connected university, military, and defence computers to exchange research data and to study communication during nuclear attack. The network developed prototype procedures for remote log-on, file transfer, electronic mail, and mailing lists.

Protocols

Other networks were being developed in parallel with ARPANET. This created a need to link different networks with different protocols. The Transmission Control Protocol/Internet Protocol (TCP/IP) permitted any file to be sent from one network to another as a binary string. Users at each end simply used identical software to encode and decode the file. The success of TCP/IP made the Internet possible. Networks connect to the Internet through a gateway that translates network-specific protocols into the standard TCP/IP. The Federal Task Force on Digitization (1997) identified more than 60 protocols in use by federal departments and specified the advantages and disadvantages of each.

Applications

The next stage in the evolution of computer networks was the development of user applications that did not require specialized knowledge of a computer command language (usually UNIX). These included information search services, such as Wide-Area Information Service (WAIS), Archie, and Veronica; file retrieval services, such as File Transfer Protocol (FTP) and Gopher; communication services, such as electronic mail, Internet Relay Chat (IRC), and Usenet newsgroup; and remote log-on, such as Telnet. These applications substantially increased public interest in and use of the Internet.

Graphical user interface

A graphical user interface (GUI) allows the user to control a PC by clicking on graphical objects (icons) on the computer screen. Development of easy-to-use PC software that could invoke Internet applications with a simple click of a virtual button greatly increased the popularity of the Internet. This resulted in an explosive growth of Internet use during the past decade as the user community shifted from computer specialists to the general population. The capability for unlimited communication to much of the world with a local telephone call and a nominal service fee is a powerful attraction.

World Wide Web

The World Wide Web added three important dimensions to the Internet—multimedia capability, hypertext links, and Web browsers. Not only could text, data, and images be sent electronically within one document, but also animation and sound. Hypertext links permitted automatic linking to any site in the world by embedding the Uniform Resource Locator (URL) in a document. Web browsers, such as NETSCAPE, integrated all Internet applications into one package transparent to the user. Browsers did for the Internet what word processors and spreadsheets did for the PC—made it indispensable. These capabilities have transformed the Internet from a technical service to a popular communications media. They have also permitted individuals and organizations to network and exchange information on unprecedented scales.

The Information Society

Information is, in a very fundamental sense, the essence of human life and its communications and application in billions of different forms determines the nature of society.

—Douglas Parkhill, *Gutenberg Two* (1982, p. 70)

Progress in information and communication technologies is changing the way we live, how we work and do business, how we educate our children, do research, and train ourselves, and how we are entertained (G7 Information Society 1995). Organizations that do not make the transition to the information society will become increasingly irrelevant. This section discusses the relevance of these revolutionary changes to the CFS.

Unlike capital, labor, land, and resources, knowledge is virtually inexhaustible. "With the coming of the information society, we have for the first time an economy based on a key resource that is not only renewable but self-generating" (Naisbitt 1984). Use of knowledge by a person does not diminish another's ability to use it. In a knowledge-based economy, the Holy Grail—unlimited growth—may, in fact, be attainable. On a

practical note, an ability to learn faster than the competition may be the only sustainable advantage.

Thousands of initiatives are currently under way to use information and communications technologies on national and global scales. An initiative of the Group of Seven industrial nations, the G7 Information Society, demonstrated how these technologies can benefit society in many areas, including education, culture, natural resources, emergency management, health, and business. Canada is developing an Information Highway and national policies to support a strong Canadian presence in the knowledge economy. Most federal government departments have Web sites to increase access to information and improve service to the public. Despite phenomenal advances, however, it will be decades before the Information Highway is fully developed. Currently some technologies are well developed and reliable; others are impractical from an operational perspective. Because most Canadians are not yet connected to the Internet, the CFS must maintain parallel distribution through traditional media during the transition period.

Laws and Policies

Federal laws define mandates, authorities, responsibilities, and required actions of ministers and federal institutions. An important challenge facing the Government of Canada is that many laws do not adequately reflect current information and communication technologies. As a result, agencies and businesses have had to interpret laws in the light of technologies that did not exist when the laws were written. The legal system must catch up, but a balanced approach is essential. A legal environment that is too restrictive would hinder advances, allowing other nations to gain a competitive advantage in developing knowledge economies. An environment that is too permissive could lead to undesired social consequences.

Policy issues include access to government information, protecting intellectual property rights, and developing national interoperability standards. Sharing data with partners involves data ownership, data access, and variable agency policies. Working in a digital environment does not change the legal and policy mandates, authorities, responsibilities, regulations, and funding of government institutions. All requirements to provide access to government information through traditional media continue to exist. In a policy context, digital media simply provide opportunities for more efficient and effective dissemination.

Emergence of electronic information and communication technologies as a method of disseminating information presents the CFS with new opportunities and challenges. A survey of 68 federal departments and agencies conducted by the Federal Task Force on Digitization (1997) found that only 29% of responding institutions have a digitization policy in place and only 39% of them had conducted a policy review or program evaluation for digitization activities. The CFS has relatively few policies related to a digital environment.

The Task Force recommended that "the federal government should develop a National Information Policy that would provide the basis to rationalize current legislation and disparate information policies into one comprehensive framework." Recommended topics included technological neutrality, access and remuneration, the role of the National Library, the Depository Services Program, essential and key information, continuing traditional access, private sector partnerships, incorporation of existing policies, provision of access points, and the monitoring and evaluation of the performance of federal institutions.

There are many institutional policies and constraints that will guide and affect a CFS knowledge initiative (K-It). A list of relevant legislation and policy guidelines is given in Appendix 1. Although most of these are established at the departmental level, the CFS should take a proactive approach to influencing institutional policies that affect the K-It, especially those relating to data, information, and knowledge.

Issues

Access to information

In Canada, 40% of all federal institutions report that the primary objective of developing digital products is to improve access to federal information. This is double the next most frequently reported objective, that of cost savings (21%). Digital access should close rather than widen the gap between information "haves" and "have nots."

However, the CFS must remember that a significant proportion of its clients and forestry stakeholders do not currently have the technology or skills to access digital content. This also applies to special needs groups, such as low-income earners, rural and remote residents, persons with disabilities, and other than official-language users. It is important to consider the level of computer literacy and inclination of users of forestry information

to access digital content. The CFS will have to continue disseminating key data, information, and knowledge in traditional formats for the foreseeable future.

The CFS has a role in providing information in support of the public good. Public good is an evolving concept that is not well defined and which leads to the dilemma of determining the types of information that should be disseminated at no cost to the user. Furthermore, digitizing all forestry data, information, and knowledge would be prohibitively expensive. The CFS will thus have to categorize and prioritize information to be made available on a tax-supported or cost-recovery basis. It can use categories for information developed by the Federal Task Force on Digitization (1997) to support its decisions on access and remuneration. The three categories are as follows:

- **Essential information:** Federal institutions are required by legislation to provide this information to citizens on a tax-supported basis under the principle of good governance. This category includes information on danger to health and safety, on rights, entitlements and obligations, and on federal activities. Access to this information would be a fully tax-supported right of citizens.
- **Key information:** Although not required by statute, this information is important to the future of the nation. It includes information aimed at promoting health, creating economic opportunity, fostering dialogue on national identity and cultural diversity, and sustaining social cohesion. Access to this information would be on a marginal cost-recovery basis.
- **Customized information:** This is value-added information that benefits individuals as consumers or a firm for commercial purposes. Examples include specialized weather forecasts, licensable technologies, detailed census data, and special-purpose satellite imagery. Access to this information would be on demand at market value.

The task force concluded that "in the interests of lifelong learning and the promotion of social cohesion, federal institutions should strive to provide as much information as possible on a tax-supported basis to citizens."

Another aspect of access is authentication. The Internet enables individuals to disseminate data, information, and knowledge to a global audience. This facilitates information sharing, informal reviews, discussions, the inclusion of divergent opinions, and the creative synergy that develops from group efforts. It also greatly speeds up the process of spreading new technology. However, much of the vast amount of information on the Internet is either outdated or inaccurate. Its credibility, timeliness, accuracy, and authority of source are difficult to ascertain. How can the user of information distinguish between raw or clean data, good or bad information, and knowledge or conjecture? Forestry agencies are also concerned with quality assurance and control of digital data, information, and knowledge. Information technology allows a digital signature to be attached to a document that would assure users that the information is an authentic and unmodified expression of the author. The CFS should incorporate in its knowledge infrastructure (K-If) a system of authentication or accreditation relating to the data, information, and knowledge that it provides.

As digitized information becomes increasingly available, searching, locating, and accessing desired information becomes more complex and difficult, particularly for the average user. The proliferation of information sources, search tools, and acquisition methods is a deterrent to effective and efficient access to forestry content. The CFS should therefore promote initiatives that identify, locate, and enable access to forestry information holdings; it should also adopt and promote a forestry thesaurus in its K-If that allows Web sites to be accessed with similar searches.

Intellectual property

Since the invention of the printing press, new technology has made it easier to reproduce copyright materials. The laws and principles of copyright applicable to new media, electronic rights, and the Information Highway are no different from those applicable to traditional media. "However, in some instances, the law may be vague in its application to new technology or the [*Copyright*] *Act* might require some amendments....[or] the administration, compliance and enforcement of the law creates a new perspective, requiring new challenges to be confronted" (Harris 1995, p. 213 and 214). Although various areas of intellectual property deal with aspects of the Information Highway, copyright is the most prominent area and the focus of the following discussion.

Copyright protection ensures that rights holders benefit from their effort and investment through recognition and remuneration. Such protection is an incentive to creators to make their works available. The Information Highway greatly increases the difficulties

of managing and protecting these rights. Knowing that the potential for unauthorized use and piracy is high, rights holders may be reluctant to make their works available for digitized dissemination. Furthermore, international copyright agreements do not address many of the challenges presented by a digital environment.

The CFS should be a model user of best copyright practices in a digital environment. Dealings with providers and users of digital content should be transparent and fair. The CFS should advocate the following to create an atmosphere of trust and openness with respect to copyright and the Information Highway:

- Determine copyright interests by ascertaining whether works from external sources are protected by copyright, what rights are involved in the intended use of the work, who is the copyright owner, and whether permission has been acquired from the owner.
- Clear copyright by locating rights holders, establishing fees for the use of a work, and obtaining reproduction permission.
- Protect copyright of works from external sources and those belonging to the Crown by technological means (encryption, keys, electronic watermarking, digital signatures), legal means (laws, contracts), and electronic copyright management information.
- Maintain the integrity of the copyright work by using digital methods to ensure that digital works are not modified without the creator's knowledge and consent.
- Increase copyright awareness by posting policies and guidelines on the Internet, using statements of copyright notice, and properly acknowledging copyright material from third parties.

Within a science environment, data ownership is a sensitive issue. Scientists are reluctant to provide access to data before publishing research results to ensure that they are properly acknowledged within the scientific community for discovering new knowledge. Holders of large databases are concerned about misinterpretation and misuse of the data. However, data, information, and knowledge collected by an employee of the Crown belongs to the Crown. Scientists do not have perpetual rights to limit access to these holdings nor do they own them. The protection of scientists' rights to have data, information, and knowledge properly attributed to their creative and intellectual efforts must be balanced with the public-good requirement to maximize access to government information. In addressing the challenges of the digital era, the CFS must be mindful of the needs of both scientists and users of information.

Forestry Knowledge

When a man's knowledge is not in order, the more of it he has the greater will be his confusion.

—Herbert Spencer (1820–1903) in *The Principles of Sociology* (c. 1886)

The forestry sector is an active participant in the knowledge revolution. Biotechnology research has produced new plant genotypes with increased growth and resistance to insects and disease. Decision-support systems combine weather observations, fire behavior models, geographic information systems, satellite monitoring, and the World Wide Web to manage large fires. Wood composites are being used to manufacture less costly, stronger, and more consistently engineered structural materials.

Forestry knowledge is multifaceted and spans a broad spectrum of spatial, temporal, and process scales. Its domains are biological, physical, and social. This section will consider how each of these facets influences the ways in which forestry knowledge should be managed. It will also look at forms of knowledge and will end with a discussion of knowledge from user and provider perspectives.

Scale

Scale is a fundamental property of data, information, and knowledge. It affects every aspect of how we manage forestry knowledge. A space-time-process framework for forestry knowledge scale and a description of some key properties of the structure follow. The effects of changing scales in a forestry context as well as the problems associated with inconsistent scales are discussed. To facilitate understanding, a metaphor of science models is used to describe knowledge scale issues.

Forest science uses models to abstract, study, and understand natural processes. In designing a model, we must first resolve the inherent conflict between how much of the real world a model will represent (span), the minimum process differences that can be distinguished (resolution), and the number of variables and interactions (complexity). As any of the trio becomes more demanding or limiting, one or both of the other two must be adjusted accordingly. For example, the

logistics of accurately modeling detailed processes become prohibitive when such details must be integrated into a larger-scale model. Further, the effort to calculate details is wasted in studying larger-scale phenomena. A landscape management model, for instance, would not use physiological processes for individual plants as its basic building block.

Conversely, large-scale models are too coarse to resolve detailed processes. For example, global climate models have not proven particularly successful when applied at regional scales. Nested models provide a partial solution to the need to span a wider scale range than is feasible with a single model. Nested models operate at two or more scales; core processes are modeled more precisely, while peripheral processes are modeled only with sufficient accuracy to describe the state of the broader environment.

Another factor affecting the acceptable span of a model is error resulting from precision, approximations, and lack of understanding. Chaos theory conclusively demonstrates that long-range weather forecasts are not possible due to the impossibility of specifying the current state of the weather with sufficient precision. As the span between a process of interest and underlying driving mechanisms increases, unavoidable approximation errors will degrade the model solution. Because of a lack of understanding, a model may inaccurately reflect important processes, which increases the apparent background "noise" level.

Another important consideration is the modeling approach. A "bottom-up" approach begins with detailed, well-understood processes and aggregates them into progressively larger-scale processes. This is the essence of the scientific method. It is possible with this approach to understand and verify the functioning of each low-level component. As we progress to increasingly complex phenomena, however, this approach becomes more and more inadequate, the whole proving to be more than the sum of its parts. Models based on small-scale experiments are often partial. Key properties of large-scale phenomena often cannot be modeled at smaller scales. A good example of success with this approach across scale boundaries can be found in meteorology, where starting with the physics of water vapor, it is possible to model a thunderstorm.

The "top-down" approach starts with the behavior of a whole system and disaggregates it into progressively finer detail. This is the essence of the systems method. The advantages of this approach are that results are compatible with higher-level processes, the chance of missing important systems-level phenomena is reduced, and collective behavior can be studied. For example, no amount of study of the components of a wristwatch will lead to an understanding of the concept of time. On the other hand, key small-scale processes may not be measurable or meaningful at larger scales. An example of the difficulties of doing this is Canada's criteria and indicators. The C&I were intended to evaluate sustainable forestry in boreal and temperate forests, but questions on how to measure inputs on the ground in ways that are meaningful at a national level remain unanswered.

The dilemma is that models (and hence the information systems that enable us to run the models for some useful purpose) must span as small a range as possible for meaning and accuracy, yet as broad a range as possible for completeness. Herein lies the art of designing an information system in which the developer's understanding of the underlying science, tacit knowledge, and experience are crucial to ultimate success. Understanding scale issues is essential to resolving the dilemma.

Space

Space is the context within which objects exist. We sense space in two ways: we see it and we see and touch objects in it. Space has many attributes. It can be defined as a location in space (place). Kennedy-McGregor (1987) describes a number of coordinate systems. Several well-known forms are latitude and longitude, *x* and *y* coordinates, and township and range. Geospatial references provide absolute locations on the face of the earth. Places (e.g., Ottawa, Lake Winnipeg) are typically located by a cross-reference from a map index to geospatial coordinates. An address is a hierarchy of place names (number, street, city, province). A relative location usually uses a map reference (or place name), along with a distance and a vector (e.g., 22 km north of…). Places can be points (e.g., weather station, research plot), lines (e.g., roads, rivers), or areas (e.g., boreal forest, Ontario).

Another spatial property is extent—how big is it? There is a boundary enclosing all points within a space and distinguishing it from outside spaces. Relativity indicates, however, that a space is defined by the objects surrounding it; the two are inseparable (Dossey 1982). This is consistent with the view that systems must be studied within the context of the environment that surrounds them (Simard 1970). Sets of multiple spaces can be structured as polygons, or predefined boundaries enclosing sets of attributes (e.g., soil types within an administrative area). A boundary can also be defined

Table 1. Spatial scale-classes for forestry.

Scale-class	Class size (upper limit)	Examples
Molecular	10^{-6} mm	DNA, H_2O
Particle	10^{-2} mm	Cell, fiber
Point	10 cm^2	Seedling, test tube
Site	10 m^2	Tree, weather station, truck
Area	1 km^2	Forest, lake, neighborhood
Regional	10^3 km^2	Ecozone, river basin, province
Land mass	10^6 km^2	Climate zone, country
Global	10^8 km^2	Atmosphere, ocean, continent

through homogeneous attributes (e.g., the area defined by a specific soil type). Finally, sets of areas can be based on a cell (or pixel) structure, with each space having a uniform area (e.g., 1 km^2).

Space also has scale. A geneticist's notion of space differs from a landscape ecologist's; "space" to a physicist is not the same as "space" to a cosmologist. Forestry spans a considerable range of spatial scales, from molecules to the planet earth. Any scheme to classify spatial scales is arbitrary; class names are not distinct and upper-limit boundaries on the classes are difficult to set. **Table 1** lists eight spatial scale-classes for forestry, each spanning two to four orders-of-magnitude. Large class-sizes are necessary to span the full spectrum of spatial scales relevant to forestry without creating an unwieldy schema. The information is organized from the smallest to the largest class-size.

Time

Time is the context within which events occur. Although we are influenced by time-related biological cycles such as the circadian rhythm, we do not have a specific organ that senses time in the way that, for instance, our eyes sense light. Furthermore, each rhythm is different. What would we choose as a time reference? Awareness of time varies depending on its context. Pleasant experiences seem to pass quickly; unpleasant ones seem to linger interminably. We can, however, precisely measure time. Kennedy-McGregor (1987) discuss several time coordinates. Instants are absolute references, typically defined by clock time or calendar date. Time can also be based on the occurrence of an event (e.g., when a fire is detected, when an activity begins). Unplanned events cannot be positioned on a time scale until they occur. Durations integrate all instants on the time scale between the beginning and end of a period. Relative times typically use an instant or an event as a reference

Table 2. Temporal scale-classes for forestry.

Scale-class	Class size (upper limit)	Examples
Instantaneous	1 second	Electronic communication, chemical reaction
Immediate	1 minute	Harvesting a tree, telephone call
Brief	1 hour	Weather, physiological process
Current	1 day	Diurnal cycle, fire detection
Short-term	1 week	Vegetation moisture, resource mobilization
Mid-term	1 month	Drought, insect outbreak
Seasonal	1 year	Growth increment, annual report
Long-term	1 century	Tree rotation, fire regime

point, along with a duration (e.g., "submit a report before 2 PM today").

The dynamic nature of time adds an important concept. In the broadest sense, western cultures view time with a linear monotonic model—flowing from the past through the present to the future (Dossey 1982). From the perspective of scale, the past and future can be viewed as mirror images. Thus, scale can be defined in terms of absolute distance from the present. The recent past (leading to the present state of nature) is comparable to the near future (which will result from the present). The essence of these linkages is that scientific models can predict cause and effect relationships at short temporal scales.

Most current events cannot be directly related to historical occurrences. For example, last year's weather tells us little about what to expect today. Major events that result in a different equilibrium level are an exception. For example, the printing press opened the way for mass education and communication, the steam engine led to the industrial society, and on a smaller scale, a major forest fire or a harvest leads to a new forest.

Climate is an important long-term process for forestry. Long-term information focuses on distributional statistics, such as averages, maximums, and totals. These are the foundation for long-term planning but are of limited usefulness for short-term management. Distant future events are unpredictable beyond assuming average distributions. A changing underlying base (e.g., climate change) negates even this limited application.

It is useful to define an intermediate category of past and future, one that combines near and distant

predictions. Prediction skill for weather degenerates rapidly beyond a forecast period of a few days. In contrast, large-scale processes, like great ships, do not readily alter course. Persistence is a meteorological equivalent to momentum and inertia. For some processes, such as drought, it is possible to start with current conditions and extrapolate into the immediate future with greater accuracy than by either forecasting or climatology alone.

Another important attribute of time is delay. The impact of delays on the dynamic behavior of feedback systems was well illustrated by J. Forester (1961). He described driving an automobile as a feedback process:

> The information and control loop extends from steering wheel, to automobile, to street, to eye [to brain, to nervous system], to hand, and back to steering wheel....Suppose the driver were blindfolded and drove only by instructions from his front-seat companion....Still worse, if the blindfolded driver could get instructions only on where he had been from a companion who could see only through the rear window.

Delay is important to all feedback systems, particularly when they involve human interaction. Delays lead to undershooting and overshooting targets. The impact of such oscillations can range from little (e.g., the temperature control on a furnace), to significant (e.g., agricultural cycles where supply and price oscillate over periodic time intervals), to catastrophic (e.g., system cycles where the amplitude increases and eventually the system collapses). In studying a national air-tanker fleet, Simard (1973) found that although centralization resulted in scale economies, transfer delays tended to cause system instability, as evidenced by the undershooting and overshooting of appropriate resource levels.

Although time and space are independent, they combine in an important way—the greater the distance between places, the longer it takes to physically move from one to the other. Distance is no longer a significant factor in electronic communication, but it will always be a major consideration for time-dependent functions involving physical resources. For instance, in the case of wildland fire management, no practical means exists to mobilize and move suppression resources long distances and to use them the same day. Once local resources are fully committed, strategic planning shifts to expected fire activity 1–2 days in the future.

As with space, time also has scale. A meteorologist's notion of time differs from a climatologist's; "time" to a zoologist is not the same as "time" to a paleontologist. Unlike with spatial scale-classes, however, a choice of eight temporal scale-classes stems naturally from well-defined boundary values. They range from one second to one century, placing speed-of-light and geologic processes outside our field of interest. **Table 2** lists eight temporal scale-classes for forestry along with class boundaries and examples. Although, as with space, the terms are not mutually exclusive, the precise boundary limits provide a clear structure.

Process

Process is the method by which a system performs work. All open systems transform inputs from a higher-level environment into outputs that affect their environment. Natural systems are controlled by static, dynamic, flow-through, or feedback mechanisms. Social systems are more complex, in that they also set goals based on perceived environmental needs, monitor their impact on the environment, and use memory, reasoning, and learning to control their processes.

Process has scale, which may be thought of as the "distance" between cause and effect. For example, the passage of a cold front can be linked to the physics of water vapor. If we assume that cause-and-effect relationships flow from high to low levels and back to high levels, then the total number of actual process interactions must increase geometrically as the scale range increases linearly. This is not the same concept as process complexity (e.g., plant growth), where, with proper understanding, an input may be linked directly to an output, without the intervening steps.

Unlike space and time, which are continuous, we tend to group processes into functional systems. Processes at one scale can be viewed as an aggregation of processes from the next lower scale class. Individual lower-level processes remain intact and identifiable as components, while their collective behavior generates higher-level phenomena often not derivable from the constituent parts. Skipping one scale-class can be viewed as an integration, in that individual lower-level components are no longer identifiable; only their collective output is significant.

Table 3 lists eight process scale-classes for forestry. They reflect a seemingly natural progression from a micro-level to a global level. Unlike space and time, there is no metric that defines the class boundaries. Like space and time, although the class names are not

mutually exclusive, the examples illustrate the trend from the smallest to highest scales.

The micro-scale encompasses basic physical, biological, and cognitive relationships—in essence, basic science. Relationships are derived from the fundamental laws of physics, microbiology, and cognition. This scale is the source of all knowledge of first principles. Micro-scale processes are normally only amenable to analysis or manipulation in a laboratory setting.

The mechanical scale includes processes that are one-step removed from the basic sciences such as physics and chemistry. Mechanical-scale processes are in the realm of engineering, biology, and psychology—the applied sciences. A well-developed knowledge base links these processes to those at the micro-level. Process models are typically based on rigorously developed relationships. These processes usually involve large-scale laboratory research or small-scale field studies.

The sensory scale involves processes that are sensed by people. On a practical level, it is the scale at which physical work is performed. We have observed sensory-scale processes since evolving as a species. Science generally begins with sensory observations. Consequently, more is known (in an empirical sense) about relationships between sensory-scale processes than between processes at other levels. In this class, mechanistic processes, such as temperature, cell division, and individual behavior, are aggregated into weather observations, plant growth, and human activity, respectively, through reasonably well-understood linkages. Although sensory-scale processes can generally trace their functioning back to the micro-scale, the linkages are often incompletely understood.

The meso-, or middle, scale operates at larger than human perspectives. Generally, we sense meso-scale processes through their components. For example, we recognize the cumulonimbus clouds that indicate a thunderstorm in the distance, but we cannot see the cold front of which it is a part. We can observe a plant community, but we cannot directly observe competition—a process that determines the characteristics of the community. Some meso-scale processes are artificial constructs intended to aid in managing or conceptualizing integrated systems, such as fire-danger rating.

Table 3. Process scale-classes for forestry.

Scale-class	Examples
Micro-	Radiation, genetic manipulation, personal attitude
Mechanical	Temperature, cell division, individual behavior
Sensory	Weather observation, plant growth, human activity
Meso-	Thunderstorm, competition, group productivity
Synoptic	Cold front, ecosystem, organizational budget
Strategic	Drought, landscape, agency mandate
Macro-	Climate, ecozone, government
Global	Climate change, biosphere, international treaty

Synoptic-scale processes are characterized by comprehensiveness, or breath. Although well defined in meteorology (e.g., cold front, air mass), in forestry, synoptic-scale processes are virtual terra incognita. At this scale, organizational and social processes are much better understood than physical and biological processes. We can name synoptic-scale processes and we are mandated to measure things at this scale (e.g., fire severity, forest health), but our current level of knowledge is, at best, rudimentary. We have yet to adequately define the concepts, much less learn how to measure, analyze, and model them. Currently, our models are limited to calculating innumerable lower-scale relationships and tabulating statistics—an unsatisfying and inefficient process. Clearly, if we do not understand synoptic-scale processes, we cannot understand how they relate to adjacent scales.

Strategic-scale processes are of major importance to the functioning of the whole. They include seasonal drought, landscape management, and organizational mandates. At this level, individual events are no longer of interest, unless they are of sufficient magnitude to affect the whole. At this level, analyses tend to involve sampling, in the sense of running lower-level process-based models for selected scenarios to represent the range of expected conditions and then extrapolating to the whole. Because of our limited understanding of meso- and synoptic-scale processes, we tend to skip them and directly address strategic issues. Ultimately, understanding meso- and synoptic-scale processes will probably be key to analyzing the increasingly complex strategic issues currently facing forestry.

Macro- or large-scale processes relate to entire systems and organizations. Examples include global circulation, stability of ecozones, and government policies. Some macro-scale processes are also artificial constructs; climate, for example, is an analytical method for integrating weather over long periods. At the macro-scale, only integrated analyses are possible, with inputs and outputs in the form of distributional statistics. We understand macro-scale processes better than meso-, synoptic, and strategic-scale processes; however, our

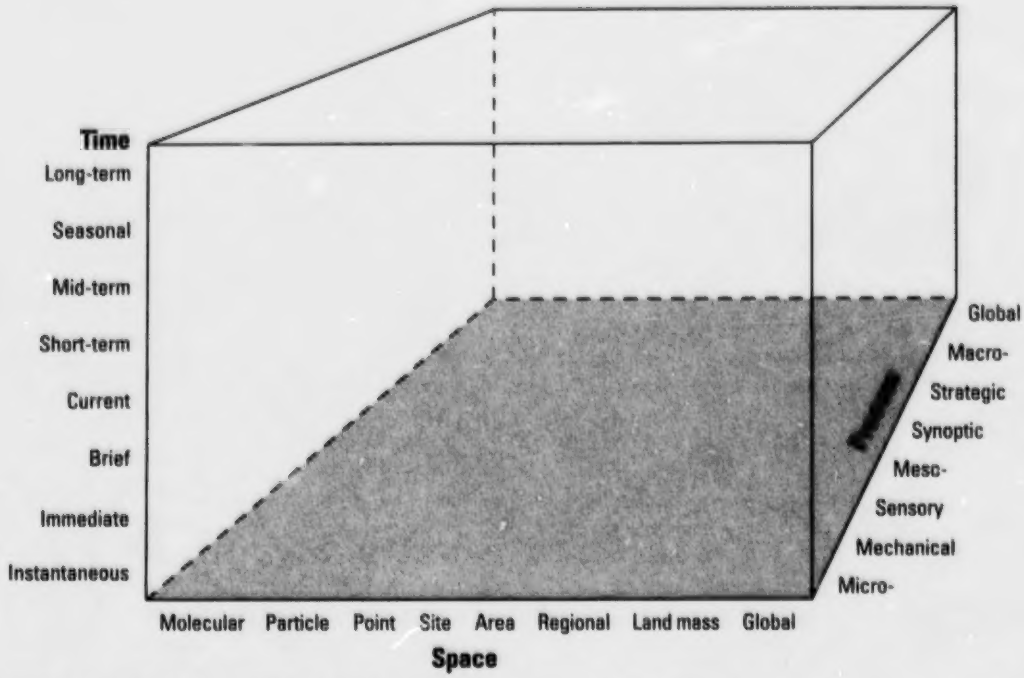

Figure 1. Framework for classifying space, time, and process scales for forestry.

knowledge is essentially confined to this scale (and the global scale) because of our poor understanding of the other three processes. Nevertheless, attempting to link back to the basic sciences through meso-scale processes would probably not be worthwhile; chaos theory dictates that it is impossible to specify the state of nature with sufficient precision to conduct meaningful analyses.

Global-scale processes integrate everything. Examples include climate change, the biosphere, and international treaties. Until recently, there were few models that dealt with forestry issues at a global scale. We have made considerable progress during the last few decades in understanding processes at this scale, although our knowledge is still limited. Success at this level will likely be predicated on an ability to better aggregate macro-scale processes.

Scale framework

The eight classes for space, time, and process have been combined in **Figure 1**. Although processes can span a range of spatial and temporal scales, the framework assumes that for every management decision or forestry issue there is an appropriate spatial, temporal, and process scale associated with it. Furthermore, as the process scale changes, the temporal and spatial scales tend to change correspondingly. However, any space in the three-dimensional framework can be populated. For example, micro-climate integrates weather over the long term at specific points, while sunspots affect the entire planetary atmosphere in a few seconds.

The scale framework has direct implications for scientific models and information systems. Simply put, attempting to develop either a model or an information system that spans too broad a range of scales is unlikely to succeed. At best, it will inefficiently perform much unnecessary processing of detail that does not materially affect the final outcome. Furthermore, our current understanding of how to properly transfer data and information between processes at different scales is limited. Alternatively, developing a model or information system at scales that are too small or too large for the decision or issue at hand will probably miss important larger- or smaller-scale processes, respectively.

An information system should attempt to span no more than one scale-class. This will maximize both processing efficiency and the capture of relevant information. When this is not possible, nested systems can be used to span two scale-classes; that is, a smaller-scale

system processes important details within a larger-scale system that captures a broader context. This approach is now standard for weather forecasting and global climate-change modeling. Crossing more than two scale-classes generally precludes direct cause-and-effect linkages. In such cases, one must resort to sampling small-scale detail and statistically extrapolating to larger scales. Such an approach is typically used for forest inventories.

Forms of Knowledge

Philosophers, since Aristotle, have debated the organization of knowledge. Francis Bacon (1561–1626) is generally credited with being the originator of the framework that parted with the Aristotelean approach and led to modern taxonomies. During the last century, forestry classification systems, thesauri, and species nomenclature have matured into generally accepted standards. Interaction with the rest of the world will require adopting and implementing such standards to organize CFS knowledge infrastructure (K-If) content. Discussions of which standards to adopt is best left to librarians and taxonomists, who are the most experienced with the subject.

We will look at knowledge from a knowledge management perspective, that is, how to organize and manage different forms of knowledge (data, information, or knowledge). The form affects what we do and how we do it, which in turn influences the infrastructure and tools that we use. Although each form is discussed separately, the borders between the knowledge forms are not closed.

Data

Data are the "facts" of knowledge; they are recorded observations and measurements. Although data carry information, they must be interpreted to extract it. Organizing data is essentially a technical problem. People who are looking for data intend to analyze the data to extract the information they contain. This is a key distinction between management of data and management of information. Metadata (data about data) are essential for finding the data, describing their content, and determining the method by which they were acquired, the processor needed to access them, and the data format, which are all needed for analysis and interpretation.

The classification structure for data depends on the type of data, that is, whether the data are spatial, temporal, or thematic. In other words, what is the most important thing to know—the place to which the data relate (e.g., maps), when they were recorded (e.g., the date), or the subject matter (e.g., insects)? These determine the first level in a metadata hierarchy and file organization. Clearly, a data structure may involve a combination of two types of data, or less likely, all three; these would constitute secondary and tertiary levels in the metadata structure. Once this is determined, there are many database management systems that can do the work of data storage and retrieval.

Users accessing data may want an entire database; if so, they need only find the data and transfer them electronically. These users most likely have sufficient technical capability to do their own analyses and the K-If would only have to be concerned with accessibility. In terms of user interaction, such data only differ from information in its metadata requirements.

However, users will more likely want a subset of a large database. In such cases, a data-mining engine or database management system with query capability is needed to select the desired sample. Conversely, users may want to combine data from multiple databases, in which interoperability among databases becomes the central issue. These users are likely to need built-in data analysis capability ranging from tabulating simple statistics to running complex models. Sophisticated systems also include report generation subsystems to produce tables and graphs of the data and results.

Information

Information is the "what" of knowledge; it is data that have been interpreted. Information is normally accessed in final form; processing is not required. Here, the key issue is finding and retrieving what one is looking for.

Developing an information taxonomy that incorporates the full range of attributes, types, users, and providers of forestry information, yet provides rapid and easy access to whatever is needed, will be challenging. Users require a multidimensional framework capable of searching from many different perspectives, depending on the user's needs. They also need a matrix structure so that they can switch from one category to another at every stage of a search. Finally, users require access to all related information, regardless of the starting point of a search. Clearly, none of this is possible with traditional one-dimensional lists. **Table 4** lists categories into which forestry information may be organized.

Table 4. Suggested categories for organizing forestry information.

Category	Examples
General	Promotional, public relations information
Governance	Laws, policies, regulations, standards
Organization	Plans, information on structure, administration, operations
Activities	Announcements on meetings, conferences, presentations, visits
Location	World, country, province, community
Directories	People, organizations, companies, associations
Collections	References, reports, articles, photographs, data, insects
Products	Supplies, equipment, consultants
Function	Silviculture, fire management, harvesting, research
Learning	Universities, courses, training
Issues	Climate change, sustainability, biodiversity
Forums	Discussion groups, bulletin boards, newsgroups, list servers
Search	Internal: data and information bases; external: the Internet

Each forestry information category should link to the specified type of information at various levels within participating network and program Web sites (below home pages). Different parts of each site might be listed under several attributes. It would be helpful to be able to cross from one entry perspective to another at lower levels in the hierarchy. For example, a user might start with activities, or start with location and then go to activities, or start with a particular function and then go to activities. The K-If should develop a standard look and feel so that each category would appear to be part of a whole. Furthermore, different categories could be accessed with different methods. Location-specific information could be found through image maps; names with alphabetical directories; products with a search form; functions with a subject list. Alternatively, one type of information could be found through an image map, an alphabetical list, or a search engine.

Knowledge

Knowledge is understanding "how" things relate to each other. Knowledge comes in two basic forms, explicit and tacit. Explicit knowledge is that which has been formalized, for instance, through textbooks, scientific publications, and recorded experiences. From a management perspective, written explicit knowledge can be disseminated and accessed with the same search and retrieval procedures that are used for information.

This section will focus on accessing tacit knowledge—the stuff in people's heads—and explicit knowledge that has been formalized through artificial intelligence and expert systems.

Tacit knowledge comes in various forms, such as education, training, self-learning, expertise, experience, skill, and corporate memory. To access tacit knowledge, one needs to find the person or persons who have it and interact with them. The interaction can take various forms, such as presentations, discussions, questions and answers, or briefings. In all cases, it involves an interpersonal exchange.

In providing access to tacit knowledge, the first task of the K-If is to enable the searcher to find the subject-matter contact. This is usually done with a directory of expertise, in which the primary search category is subject matter with a link to contact information. The second task is to support personal interaction. Telephone, fax, correspondence, and personal visits are traditional methods whereby this can take place. The K-If should also support interpersonal interaction through e-mail, discussion groups, bulletin boards, list servers, and shareware.

An expert system begins with tacit knowledge that has been solicited from an expert, formally codified, and entered into a knowledge base. An inference engine uses if-then-else search heuristics to search the knowledge base, given input parameters provided by the user. Such systems are most advanced in the field of diagnostics (e.g., disease identification). Expert systems have begun to emerge in the field of forestry; they should eventually be linked with the K-If as expert modules.

Natural language processors are another form of artificial intelligence-based systems designed to facilitate interaction between nontechnical users and complex systems. The efficacy of current natural language systems associated with word processors, graphics packages, and spreadsheets suggests, however, that further development will be needed before they are really useful.

Knowledge Perspectives

There are many legitimately different perspectives on most issues. They stem from reasons such as functional mandates, varying roles, technical considerations, and personal views. The K-If will have to recognize different perspectives, enabling each perspective to dominate in areas where it is necessary or relevant while maximizing areas of commonality.

Table 5 lists potential users and providers of forestry information. In essence, the list includes any person or organization with an interest in forestry. The key point is the considerable diversity of interests, with corresponding diversity in information needs and format requirements. The communication adage that a message must be tailored to the intended audience applies equally to digital media. Information can be presented in many formats (e.g., a science paper, a report, a press release, a briefing note, a how-to booklet). One size does not fit all; information formatted differently from that expected by an intended audience may not even be read, let alone understood.

From a provider perspective, knowledge is inextricably linked to organizational mandates. Some providers strive to be objective; others selectively disseminate information; still others use information to further an agenda. Users have to understand that all information is not created equal; they must sift and winnow among what is available and select what is most appropriate for their needs.

Another way to view knowledge perspectives is with Venn diagrams (Figure 2). In each case, the totality of all perspectives is defined by the outer boundary of the circles. The knowledge infrastructure functions in the overlapping areas. The diagrams are conceptual only; no attempt has been made to establish actual or potential overlap for any set of perspectives. In cases where the areas of overlap have a specific identity and meaning, these are identified.

Figure 2a represents K-If linkages between clients, partners, and an organization. Within the organization, the focus is on producing and exchanging knowledge between the various domains; linkages are internal; and access is controlled entirely by the organization. Linkages to clients are one-way and are open to and accessible by everyone. Partnerships involve content that is produced and "owned" by others. Linkages to partners are two-way; they may or may not be publicly accessible, or accessible only in a limited way. Each linkage with a partner involves negotiated agreements detailing how information will be managed. The overlapping area defines the realm of the Internet and World Wide Web—the networks and software systems that enable global exchanges of content among various groups.

Figure 2b represents CFS functions: science, administration, and management. Science is, by its nature, open; knowledge is generally freely shared (after the results have been published). Administration is the opposite: most information is confidential, and access is limited to those who have a direct need and the authority to access the information. Management information, such as reports on progress or budgets, lies between the two extremes. The overlapping area is the realm of the Common Office Environment, the office automation systems that support much of the work of the CFS and exchanges of knowledge among CFS functions.

Figure 2c shows the three CFS branches: science (Science Branch), policy (Policy, Planning and International Affairs Branch), and industry (Industry, Economics and Programs Branch). The purpose of science is discovering new knowledge. Science focuses on knowledge synthesis; its methods are primarily quantitative; and its successful results are normally published. Policy must balance many conflicting interests inherent in any socioeconomic issue. Methods used by policy-makers are primarily subjective; only final "approved" documents are openly disseminated. Industry focuses on competitiveness; much of the data, information, and knowledge is proprietary in nature and not appropriate for distribution at any time. The overlapping area between quantitative and subjective methods defines the domain of expert systems.

Figure 2d addresses different participant roles in knowledge management: provider, user, and systems manager. Without someone to provide content, knowledge infrastructure is a hollow shell. Most of the work and responsibility for the content falls to those who originally produce it. Those who use and reformat knowledge into specific products often reap most of the visibility and benefits. Those who manage the systems that support knowledge processes focus on technical functionality; their role is essentially independent of the content or its intended use. The overlapping area defines the cultural realm of shared vision, values, and organizational purpose, which will be the key to successful implementation of a CFS K-If.

Table 5. Potential users and providers of forestry knowledge.

Users	Providers
Politicians	Governments
Executives	Agencies
Administrators	Nongovernmental organizations
Forestry officials	Forest management agencies
Scientists	Universities
Educators	Schools
Reporters	Media
General public	Interest groups

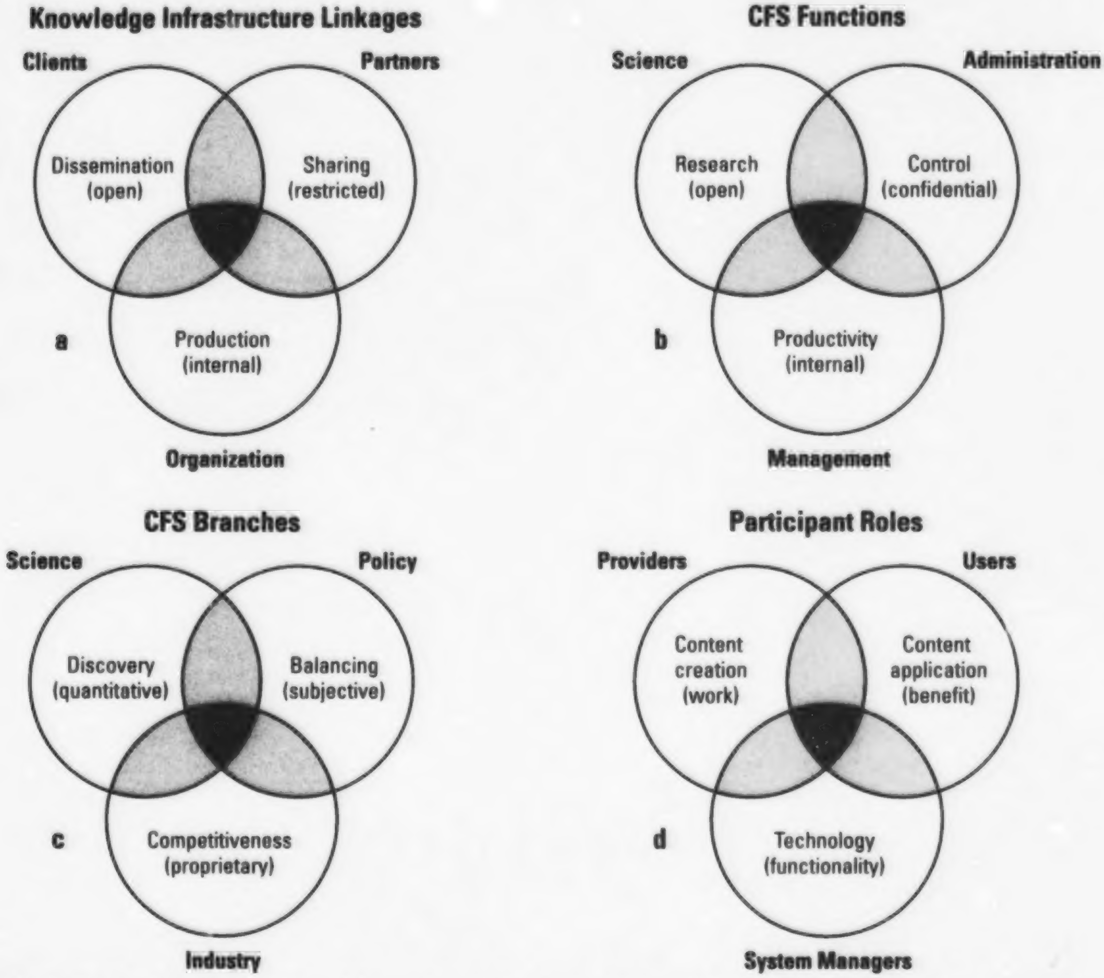

Figure 2. Knowledge perspectives on **(a)** knowledge infrastructure linkages; **(b)** Canadian Forest Service functions; **(c)** Canadian Forest Service branches; and **(d)** participant roles.

CFS: A Knowledge Producer

As we enter the next millenium, Canada must become the world's "smartest" natural resource developer: the most high-tech; the most environmentally friendly, the most socially responsible; the most competitive and the most productive.

—The Honourable Ralph Goodale, Minister of Natural Resources Canada (Natural Resources Canada 1999)

As a science and technology agency, the Canadian Forest Service (CFS), Natural Resources Canada (NRCan), has been creating knowledge for a century; it is inextricably linked to creating new knowledge. The CFS is also a key player in facilitating sustainable forest management at the national level. It owns substantial knowledge assets that contribute to enhancing all aspects of forestry in Canada and is responsible for managing these assets in ways that benefit Canadians and the forest sector. Finally, for the CFS to continue to be recognized as a leader in forest science and technology, it must participate in and have a visible presence in the knowledge-based economy.

Organizational Structure

The goals of the CFS knowledge infrastructure (K-If) are to manage data, interpret information, and synthesize knowledge to support the CFS mission, provide digital

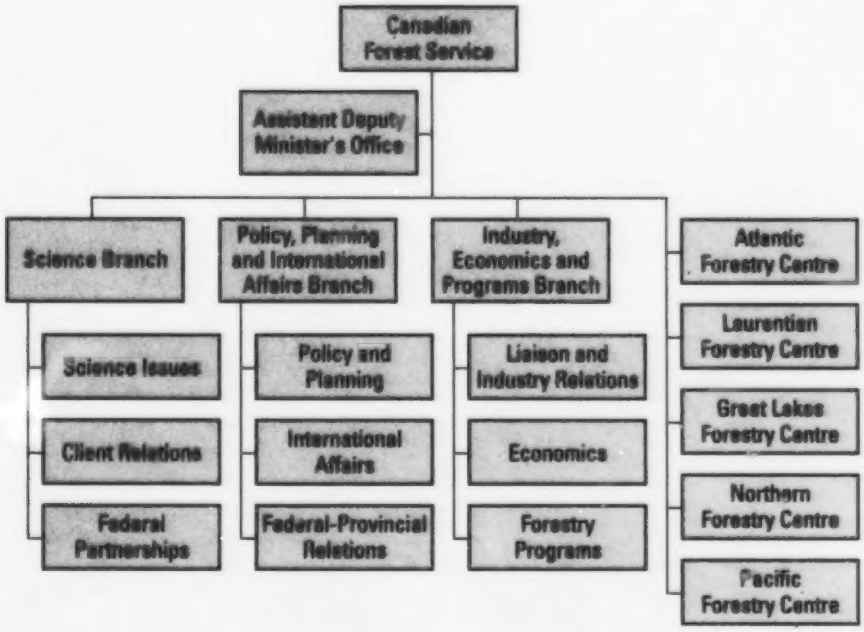

Figure 3. Canadian Forest Service organizational structure.

access for clients, and exchange information with partners. Understanding the organizational structure of the CFS is essential to accomplishing these goals. The CFS mission is to promote the sustainable development of Canada's forests and competitiveness of the Canadian forest sector through integrated science and policy. The mission is implemented through the office of the Assistant Deputy Minister (ADM), science and technology (S&T) networks, five research centers, and three headquarters (HQ) branches. The organizational structure is shown in **Figure 3**.

Assistant Deputy Minister's Office

The ADM's Office supports the ADM at the sectoral and departmental levels. Management Services Division develops, maintains, and monitors the administrative framework, practices, and issues for the CFS. The Communications Division develops communication strategies and joint activities for the CFS.

Science and technology networks

The CFS science and technology (S&T) program reflects the evolving circumstances and needs of Canada's forest sector. The S&T program promotes sustainable forest management and a competitive Canadian forest sector by creating scientific knowledge and developing new technology. The program tackles strategic and fundamental national and international issues by

- integrating information and supporting decision-making;
- maintaining and enhancing forest ecosystem health;
- maintaining and enhancing forest ecosystem productivity;
- establishing global forest systems;
- enhancing industrial competitiveness and preserving market access.

The CFS has adopted a national network-based approach to deliver the S&T program. The networks enable the CFS to address national and international issues while delivering research programs through regional research centers. Networks are formed around policy issues and associated research priorities at the regional, national, and international levels, according to the mandate, resources, facilities, and expertise of the CFS.

Each network is led by one of five CFS research centers. The CFS Headquarters Science Branch in Ottawa coordinates the national S&T program. Regardless of location, the networks are national and international

in scope, strategic in their approach to forest science and policy issues, and managed so that outputs exceed the sum of what individual centers could achieve alone. The networks are as follows:

- **Climate Change**—Provides leading-edge Canadian expertise related to climate-change impacts on forests and forest ecosystems and forest-based mitigation and adaptation options to address the climate change issue.
- **Effects of Forestry Practices**—Assesses and develops forestry practices for use in the sustainable development of Canada's forests.
- **Fire Research**—Increases understanding and ability to manage wildland fire within the context of the sustainable development of Canada's forests.
- **Forest Biodiversity**—Provides the scientific foundation for the development of forest biodiversity policies.
- **Forest Ecosystem Processes**—Conducts research to determine how fundamental ecological processes affect the productivity and resilience of forest ecosystems.
- **Forest Health**—Monitors the health of Canada's forests.
- **Landscape Management**—Develops scientific understanding and decision-support tools to assist in decision making in the sustainable management of Canada's forests.
- **Integrated Pest Management**—Advances the development of ecologically acceptable methods for managing forest pests and contributes to integrated pest management and sustainable forest development.
- **Socio-Economic Research**—Provides leading-edge socioeconomic research in support of NRCan's vision of being a global leader in sustainable development.
- **Forest Biotechnology**—Generates knowledge and technology based on life processes that apply to improving quality, productivity, and health of trees and their utilization within ecologically and genetically sound principles.

Forestry centers

The Atlantic Forestry Centre (AFC) is located in Fredericton, New Brunswick. The center's regional responsibilities include the provinces of Newfoundland, Prince Edward Island, Nova Scotia, and New Brunswick. The center maintains research laboratories, greenhouses, nurseries, and administrative offices. About 32 km outside Fredericton, the Acadia Experimental Forest maintains permanent research plots and provides sites related to the AFC's research programs. The AFC also administers a research component in Corner Brook, Newfoundland. The AFC provides scientific and technical leadership for the Forest Health and Forest Biodiversity networks. The research program includes activity in most of the national S&T networks.

The Laurentian Forestry Centre (LFC) is situated in Saint-Foy, Quebec. The center's regional responsibilities are with the province of Quebec. The center is mandated to provide leadership in forestry research and foster the establishment, transfer, and use of forestry practices required for sustainable development. The LFC is the lead center for the Forest Biotechnology Network and Forest Ecosystem Processes Network. The latter is led in conjunction with the Great Lakes Forestry Center. The LFC's Policy and Liaison Group provides liaison with all Quebec forest industry stakeholders and takes an active role in technology transfer to make the greatest possible contribution toward sustainable development of forest resources. The Group also manages three regional programs in Quebec: the Model Forest Program, the First Nation Forestry Program, and the Testing, Experimentation and Technology Transfer in Forestry Program.

The Great Lakes Forestry Centre (GLFC) is located in Sault Ste Marie, Ontario. The center's regional responsibilities are with the province of Ontario. It is the lead center for the Integrated Pest Management and Forest Ecosystem Processes networks (the latter is co-led with LFC). Research is also being conducted in a variety of other forestry-related areas. The GLFC has entered into many cooperative research agreements with the forest industry in Ontario to satisfy the need for new knowledge within the industry.

The Northern Forestry Centre (NFC) is located in Edmonton, Alberta. The center's regional responsibilities include the provinces of Manitoba, Saskatchewan, and Alberta and the Northwest Territories. It is the lead center for the Fire Research Network, Climate Change Network, and Socio-Economic Research Network. The NFC also participates in research activities related to most of the other networks. The Regional Development Program coordinates the activities of federal–provincial/territorial forestry agreements and

manages branch offices in Prince Albert, Saskatchewan, and Winnipeg, Manitoba. It also conducts research to stimulate the economic use of the forest resource.

The Pacific Forestry Centre (PFC) is located in Victoria, British Columbia. The center's regional responsibilities include British Columbia and the Yukon Territory. The PFC provides essential forestry research to secure the social, economic, and environmental value of the forest for future generations. It is the lead center for the Landscape Management and the Effects of Forestry Practices networks. The PFC is also responsible for regional programs related to forestry research, development, and technology transfer; for forest management on federal and Indian lands; for production of economic information, statistics, and advice; and for addressing industry, trade, and international issues and opportunities to support the forest sector.

Headquarters branches

The Science Branch links results from the science and technology program to policy formulation, to forest sector competitiveness, and to responses on issues. The Science Division integrates forest science and policy, delivers nationally synthesized science-based information and knowledge, and identifies and responds to emerging issues. The Federal Partnerships Division coordinates relations with other federal departments and agencies, national research granting councils, and universities. The Client Relations Division compiles national advice on the CFS S&T program, provides marketing advice, produces scientific and technical publications, disseminates information, and manages the FERIC partnership and CFS involvement in the NRCan Science and Technology Internship Program.

The Industry, Economics and Programs Branch addresses key issues on trade, industrial policy, and market access and facilitates sustainable development of the forest industry. The National Forestry Database Program compiles national forestry statistics, maintains the national forestry database, and disseminates data to clients. The Liaison and Industry Relations Program interacts with national and regional forest industry associations. The Model Forest Network provides a framework and strategic direction for developing local sustainable forestry initiatives and disseminating results. The First Nation Forestry Program enhances the capacity of First Nations to sustainably manage forest reserves, operate forest-based businesses, and increase forestry employment. The Federal Lands program manages forests and timber sales on some federal properties, on behalf of federal institutions.

The Policy, Planning and International Affairs Branch coordinates national forest policy development, federal–provincial and international relations, and sector-wide strategic and operational planning. The branch also manages the International Forestry Partnerships Program on behalf of the Canadian Council of Forest Ministers. It is the sector conduit for departmental initiatives such as NRCan's Performance Measurement Initiative and Sustainable Development Strategy. This branch manages several major files, including the National Forest Strategy, the criteria and indicators of sustainable forest management, the International Forest Convention, and the State of Canada's Forests.

Organizational Processes

Developing a **knowledge infrastructure** at the CFS is an engineering problem. What should it do? How will it work? How long will it take to design? How much will it cost? What resources are needed? These questions can all be successfully resolved by adhering to well-known project management principles and procedures.

Implementing a **knowledge initiative** at the CFS is a much more subtle, complex, and challenging people problem. Will it complement the management style? Will it be viewed as part of the teamwork process? Will it be disabled by bureaucracy? Will it be impeded by entrenched interests? Will people accept change? Can the organization adapt to a new environment? This section addresses these issues in the context of a CFS K-It.

Morgan (1986) presents theories and explanations of organizations as metaphors. Each metaphor implies a way of thinking on how we understand the world. Each perspective has strengths and weaknesses. The metaphors are as follows:

- Organizations as machines: Each interlocking part plays a clearly defined role in the efficient functioning of the whole. The mechanical way of thinking is so ingrained in management concepts that it is difficult to organize any other way.
- Organizations as organisms: The organizational needs and relations with the environment are the focus. Different "species" of organizations (e.g., a bureaucracy, an enterprise) vary in their birth, development, growth, decline, and adaptability to their environments.

- Organizations as brains: Information processing, learning, and intelligence are valued. Self-organization is highlighted when a high degree of flexibility and innovation are needed.
- Organizations as cultures: Values, norms, rituals, and beliefs that sustain organizations as social entities are the focus. Organizational designs are based on patterns of shared meaning that guide organizational life.
- Organizations as political entities: The different interests, conflicts, and power plays that shape organizational activities are emphasized. This view is based on political principles, legitimizing rules, and other factors that shape organizational life.
- Organizations as psychic prisons: In this view, people are trapped by their thoughts, ideas, beliefs or preoccupations. Organizational life is examined to determine whether people and groups are confined and controlled by conscious and unconscious processes of their own creations that prevent the organization from realizing its full potential.
- Organizations as learning entities: In this perspective, fluctuation and transformation provide insights for understanding and managing organizational change and the forces that shape the social nature of an organization.

Most of these perspectives will be found, to varying degrees, in the subsequent discussion under headings related to issues associated with developing the CFS K-It.

Management

The CFS is managed with a matrix structure. Administrative authority and responsibility is vested in five research centers, while functional strategy, direction, and guidance rests with the 10 national S&T networks. Each center leads two or more networks. Most networks have projects that involve several centers. This structure enables the CFS to respond in a coherent way to evolving national and international issues and federal priorities. Projects can be created as the need arises and disbanded when the project is complete. Project members are selected from a cadre of professionals with relevant expertise, resulting in an efficient allocation of specialized expertise. This approach also minimizes functional conflicts by incorporating a broad range of views into project activities.

A matrix structure, however, poses some challenges to organizational efficiency and effectiveness. Splitting administrative and functional responsibility can result in unclear lines of authority. Control of the budget and staffing can be problematic when competition for scarce resources is high. The normal tension between allocating resources to national, regional, and local initiatives is challenging, particularly in the light of budget reductions. Scientists are reluctant to give up the freedom to search for truth along personally interesting paths. They are even more reluctant to shift from low-priority subjects, in which they may have considerable experience and recognition, to new areas of research. This is more than simple resistance to change. The considerable specialization of modern science makes it increasingly difficult for individuals to know enough outside their specific domain to be able to contribute to the advancement of knowledge in new areas of research.

Matrix management is effective when everyone is at the same location; it becomes more difficult when expertise is spread across the country. Success depends heavily on interpersonal skills both within the project and between the project and parent functions. In theory, temporary project members have access to the permanent resources of home units. In practice, there is always more to do than can be accomplished. If line supervisors are not personally committed to projects, they will be reluctant to assign resources. Furthermore, they will view the commitment of staff and resources as interfering with their normal functions. This tends to result in project members being expected to carry on part or most of their normal,duties and may result in confusion and conflict, as members are forced to choose between the new project and their normal duties.

The success of a matrix structure is critically dependent on shared organizational vision, goals, and objectives. Achieving this will be a challenge for the CFS, with its long history and strong tradition of regional and functional lines of authority and communication. All factors considered, however, a matrix structure provides more advantages for the CFS than disadvantages. The challenge for the K-It will be to develop a broadly based consensus of support from both line and functional managers as well as processes that work efficiently and effectively within the matrix.

Committees

The CFS is strongly consensus oriented. There are formally appointed managers at all levels of the organization who have authority and are ultimately responsible for every decision. However, most decisions are based on recommendations from committees, meetings,

and staff briefings. The notion of a plural executive is fairly typical of large, complex organizations. Every decision by the CFS involves balancing different, sometimes competing, interests. No individual can be familiar with the myriad details of the many issues that must be addressed. The higher the organizational level, the more complex and difficult the choices.

The greatest positive attribute of a committee structure is the combined, integrated judgment that it can offer. Committees can incorporate a wide range of experience, knowledge, ability, and personality in addressing complex issues. They reduce conflict and promote cooperation among functional groups. Members can empathize with other members' problems. Traditionally, committees are the only formal structure for horizontal communication. Increasing the involvement of members in problem solving leads to increased acceptance and implementation of decisions. New members can grow personally by observing and learning from experienced members.

Committees also have disadvantages. They are time consuming and costly. The nature of a committee is to allow each person the opportunity to express an opinion. Meanwhile, everyone else is being paid to listen. There may also be transportation and lodging costs. Committees divide responsibility—a group rather than an individual is accountable for outcomes—so that no one is really accountable. Some members use committees to shield themselves from personal responsibility for bad decisions. Perhaps the ultimate difficulty is that committees can reach decisions based on excessive compromise. When unanimity is required, the outcome usually represents the "lowest common denominator"—an outcome so watered down as to be ineffective.

There are two key committees in the CFS, the Management Committee and the S&T Network Managers Committee. The CFS Management Committee is chaired by the ADM and comprises CFS directors general and the directors of the ADM's Office. It establishes policies; provides strategic direction; promotes internal linkages among branches and regional establishments; allocates and manages CFS resources; and provides leadership in creating a quality working environment and promoting a commitment to excellence. This committee is the formal decision-making body in the CFS.

The Science and Technology Network Managers Committee is chaired by the Director General, Science Branch, and comprises the 10 network program managers and the Director, National S&T Network Coordination. The Committee is a forum for disseminating information and decisions from the NRCan and CFS Management Committees and develops programs to implement these decisions. It also facilitates communication among the S&T networks and identifies and resolves issues resulting from management decisions by setting priorities, allocating budgets, evaluating performance, reviewing programs, and managing the organization, staffing, and workload. Although this is an informal committee, it has considerable influence on the direction of the CFS S&T program.

If implementation of a CFS K-It is to succeed, it will not only have to represent and serve the organization as a whole, but also its many branches and divisions, networks, and functions. This goal cannot be achieved without using committees. The challenge will be to adopt processes that favor synthesis and integration of divergent viewpoints while minimizing time, cost, and compromise.

Decision making

Organizations must make decisions. Whether done by individuals or committees, the decision-making process is similar:

- Define the problem: the problem, not the symptoms; the right question, not the right answer.
- Identify limiting or critical factors: constraints, such as time, cost, staff, facilities, technology, and policies.
- Develop potential alternatives: as many possible distinct alternatives; subsequent variations and combinations will likely emerge.
- Analyze the alternatives: positive and negative attributes of each alternative; quantitative measures in preference to qualitative ones.
- Select the best alternative or combination: that or those with the most advantages and fewest disadvantages; do not solve one problem by creating another.
- Implement the decision: with commitment from people to achieve the desired results.
- Evaluate the outcome: adjust the decision if necessary.

Decision-support systems synthesize information into knowledge tailored to specific decisions. They may

use sophisticated analysis techniques, process models, inference engines, and artificial intelligence processors. They can monitor processes to help identify problems, provide information on constraints, greatly facilitate the search for alternative solutions, access and run powerful analytical tools, optimize choices, provide a framework for implementation, and generate feedback on outcomes and impacts.

Administration

Large-scale administrative tasks inevitably lead to establishment of a bureaucratic framework. One of the great challenges in all large organizations, whether public or private, is to balance the need for hierarchy, specialization, rules, and impersonality against the significant dysfunctions of bureaucracy. A hierarchy maintains unity of command, coordinates activities and people, reinforces authority, and provides formal lines of communication. However, the traditional downward emphasis can block individual initiative and participation and impede upward communication. Specialization leads to increased productivity and efficiency, but also creates conflicts between specialized units, to the detriment of achieving overall goals. Rules may become the ends for behavior rather than the means for effective attainment of goals.

The inherent lack of hierarchical structure and the dynamic nature of the Web are particularly problematic for bureaucracies. The Web is not a bottle; the user cannot be forced to enter from the top. Although bureaucracies may surround information with all manner of formal trappings, these will be bypassed by most users of the Web after the first encounter. People access information because of the quality of content, not because of formal structure. The dynamic nature of the Web is an anathema to bureaucracies, where control is the essence of existence. Anyone can avoid this control and publish on the Web, taking advantage of its full power. Bureaucracies will eventually have to come to grips with and resolve these issues. Bureaucracy will affect every aspect of the K-It. The challenge will be to overcome bureaucratic barriers to progress within a context of acceptable actions.

Managing an organizational-scale initiative will require administrative support. Establishing the CFS K-If is recognized as a function of the CFS. Therefore, accounting provisions for the K-It have been incorporated in the Government Accounting System used by the CFS.

Communication

No organization can function without effective communication. However, studies have shown that only half of the information content of a message is correct after passing through six management levels (Davis 1982). There are many reasons for this, such as making an error in passing on the information, misinterpreting the information, concealing adverse information, enhancing marginal information, and biasing information to support a particular agenda. One solution is to reduce the number of links in the chain of communication or reduce the human element through automation. Another is to institute redundant networks. For example, a chain or a "Y" is more susceptible to disruption than a circle or a wheel. An open network, with lines to and from every node, is clearly the most robust.

From a communications perspective, the CFS is an archipelago. On each island, workers labor diligently to accomplish assigned tasks unaware of similar work on neighboring islands. Notes in bottles tossed into the ocean provide only sporadic clues about nearby activity. At important festivals, everyone gathers at one place and each island proudly displays its accomplishments for all to see. Everyone then canoes back home to continue as before.

A CFS K-It would be a powerful tool to support organizational communication. Accurate information could be entered once by the originator and become instantly available to everyone at all levels of the organization in its original form. Some, however, will view information as power and will see such a capability as a threat. Access to information that others do not have yields an advantage to the possessor. If everyone has the same information, it becomes more difficult to bias its interpretation. The need for a common vision of organizational purpose is key to the success of a K-It.

Whatever else a CFS K-It accomplishes, its potential capacity to enable and facilitate exchanging information within the CFS is sufficiently important, in and of itself, to justify the entire undertaking.

Informal organization

The informal organization is a network of personal and social relationships that arise spontaneously among people in a work environment. It encompasses all the informal groupings of people within a formal organization. Plunkett and Attner (1983) identify three types of informal groups, horizontal, vertical, and mixed.

Horizontal groups include persons at the same organizational level. These groups promote information sharing, provide mutual support, and facilitate cooperation in dealing with similar problems, interests, and concerns. Individual beliefs and characteristics, such as age, experience, personality, proximity, interaction, race, sex, religion, and language also lead to the formation of informal groups.

Vertical groups cross one or more organizational levels, usually within the same work area. This can have positive and negative effects. For example, the subordinate has access to a friendly ear at a higher level, but this could lead to criticism for playing politics. The superior has better communication and access to information from lower levels, but risks loss of objectivity and accusations of favoritism in dealing with the subordinate.

Mixed groups combine different levels and work areas. They are usually based on common bonds outside of work, such as similar interests, club memberships, and ethnic backgrounds.

Informal groups endure because they serve four functions: they maintain the social and cultural values that group members hold in common; provide an opportunity for status, social interaction, and fulfillment; give information; and influence the work environment.

Two characteristics of informal groups are their norms and cohesion. Norms are standards of behavior that are accepted by all group members. They may control dress standards, work practices, communication outside the group, and productivity. Failure to adhere to the norms may result in verbal reminders that can escalate to harassment, ostracism, sabotage, and physical abuse. Cohesion is the degree to which members share a group's goals. The greater the cohesion, the greater the control and the greater the group's success in achieving its goals.

Informal groups can have positive effects on the formal organization. When informal groups support the formal organization, they can increase its overall effectiveness; they can advise management, encourage cooperation between management and staff, create a feeling of acceptance and belonging among staff, provide a useful communication channel, and encourage better management by fostering openness. Informal groups can also have negative effects on an organization. They can foster resistance to change to protect existing values and beliefs, incite conflict between the formal and informal organizations, create and process false information or rumors, and advocate conformity.

Collectively, the informal organization is a system of powerful checks and balances. It can make a formal plan succeed or fail. The CFS should prepare strategies for working with the informal organization and undertake to

- Identify informal groups, their leaders, norms, and cohesiveness.
- Consider the impact of K-It actions and outcomes on the informal organization.
- Seek support and cooperation from informal groups.
- Provide open and complete communication through formal and informal channels.
- Control rumor and gossip by removing causes and providing credible facts.
- Minimize potential threats to the informal organization.

Change management

Knowledge management at the CFS is all about change. This change is not simply putting in place a new accounting system or increasing the efficiency of publication production. Developing and implementing a knowledge initiative will involve a fundamental change in how the CFS conducts its affairs. In the business world, the track record of implementing change is mixed. About one-quarter of businesses fully achieve their change objectives, about one-half achieve some objectives, and about one-quarter are classified as unsuccessful. Managing a complex organizational-scale change will be a formidable challenge for those charged with CFS knowledge management.

Most organizations face similar challenges in managing change. Difficulties arise in understanding the general nature of change, the changing vision, values, or culture, the decision-making processes, and the leadership styles; in managing organizational issues and the human aspects of change; and in evaluating the effectiveness of change.

Carr et. al. (1996) indicate five critical success factors for overcoming resistance to change.

- A shared **vision** of the desired change has been developed, articulated, and communicated by change leaders.
- The compelling **need** for change has been developed and is shared by all employees.

- Practical **means** to achieve the vision have been planned, designed, and implemented.
- **Reward** systems of the organization have been aligned to encourage appropriate behavior that is compatible with the new vision.
- **Feedback** is available at each stage of the process to monitor progress and provide information for continuous improvement.

These success factors lead to a four-phase strategy for successfully managing change: assessment, planning, implementation, and renewal.

In the assessment phase, the organization focuses on its readiness for change and its levels of understanding, ownership, and commitment with respect to change. The probability of successful implementation grows as existing organizational culture, behavior, and assumptions are increasingly aligned with those envisioned by the change. Failure to achieve reasonable alignment risks failure of the change process.

The organization must then develop a plan for implementing the change, overcoming roadblocks, and establishing a means of measuring and evaluating progress. The most important factor of the change process is the human element. A workforce that is suspicious of management's motives can cause the best planned change strategy to fail, whereas well-informed, trained, and committed knowledge workers can be a major factor in achieving success.

In the implementation phase, the organization assists individuals and teams to execute the change plan. Appropriate reward, recognition, performance, training, and communication systems are important to the success of this phase.

In the renewal phase, the organization determines its ability to capitalize on the opportunities provided by the change and to develop organizational resilience. For change to be lasting, it must be thoroughly ingrained into the organizational culture. One approach to accomplishing this is by developing a learning organization, in which adapting to change is seen as a normal part of doing business.

Learning organization

Organizational structures and cultures that served well in the past will not succeed in the emerging knowledge economy. As the world becomes more interconnected, complex, and dynamic, learning becomes an increasingly important aspect of work. A learning organization might be described as one in which continuous change, adaptation, and improvement are viewed as ordinary parts of doing business. Senge (1990) provides a framework for creating a learning organization. It requires integrating five behavioral disciplines: systems thinking, personal mastery, mental models, shared vision, and team learning.

The fundamental tenet of systems analysis is that the whole is greater than the sum of its parts. The systems approach is a conceptual body of knowledge and tools that have evolved over the last 50 years and that clarify patterns of collective behavior beyond those arising from a simple summation of component properties. Organizations are systems. Traditionally, management tends to focus on isolated components of the system and wonder why the deepest problems never seem to be resolved. A systems approach helps to identify the root cause of problems in large organizations and effective ways of changing overall organizational behavior.

Personal mastery involves lifelong learning, spiritual development, and commitment. It results in continuously increasing proficiency, clarifying and deepening individual vision and values, focusing energy on what is really important, developing patience, and seeing reality objectively. It is a cornerstone of the learning organization that the organization's capacity for learning can be no greater than the individual member's. The roots of this discipline lie in both eastern and western spiritual and secular traditions. People enter organizations as bright, well-educated, high-energy people who want to make a difference. By the age of 30, some are on a fast track; the others put in their time at work and do what matters most to them on weekends. Few adults rigorously develop their own personal mastery; and although most organizations have training programs, few of these programs go beyond increasing effective working skills.

Mental models are deeply ingrained assumptions and generalizations about life, how the world works, and how we respond to situations. Mental models of what can and cannot be done within an organization are no less deeply entrenched. Many new insights and bright ideas fail to get implemented because they conflict with powerful mental models. Continuous adaptation and growth in a dynamic environment requires that management teams change their individual and shared mental models of the organization and the environment. To do so means turning the mirror inward to

unearth internal pictures of the world and subjecting them to rigorous scrutiny. It also requires an ability to balance inquiry and advocacy and to expose individual thinking and make it open to the influence of others.

Few, if any, organizations have sustained a measure of greatness without deeply shared goals, values, and missions that bind people together around a common identity and sense of destiny. A genuine vision (not the pervasive "vision statement") leads people to excel and learn, not because they must, but because they want to. Given a choice, most people opt for pursuing a lofty goal. What is needed is a way to transform individual vision into a shared vision—a set of principles and guiding practices. This requires discovering shared pictures of the desired future that foster genuine commitment rather than compliance. Attempting to dictate a shared vision is counterproductive.

Team learning addresses the paradox of a team of committed members with individual intelligence quotients above 120 and a collective IQ of 63. Teams can learn collectively. There are many examples in sports, the performing arts, science, and management, where the intelligence of the team exceeds that of the individuals and where teams develop extraordinary capabilities for coordinated action. This involves dialogue—a genuine free-flowing of meaning through a group and allowing the group to discover insights not attainable individually. Team learning differs from discussion (with the same roots as "percussion" and "concussion"), which involves heaving ideas back and forth, in a winner-take-all competition. Team learning also entails recognizing patterns of deeply ingrained defensiveness that undermine learning; by bringing these patterns to the surface creatively, learning can actually be accelerated.

A knowledge infrastructure is compatible with and fully supports a learning organization; the two must be developed concurrently. This will involve a new way of doing business and the technology to support it. Neither initiative can realize its full potential without the other. The CFS should not invest significant time, effort, and resources to develop a K-If unless it also intends to develop an organizational culture that can take full advantage of the power and flexibility offered by the K-If technology.

Resources

Funding

The CFS is increasingly adapting to a digital environment. Through reallocation of existing appropriations, digital access to information has been achieved for a limited subset of data and information, particularly that acquired or generated in the last 5 years. The Federal Task Force on Digitization (1997) found that for 75% of federal institutions, the primary source of digitization funding is government appropriations. The CFS, like most other agencies, has achieved electronic access to information with internal funding.

Where the CFS has begun to make information available electronically, its clients have shown considerable interest. On a site developed by the Fire Research Network, users download more than a thousand files per day during the fire season. Moreover, electronic access to some information has the potential to increase awareness of nondigital information held by the CFS. This awareness, in turn, leads to client requests for materials that are not digitized and pressure for digitization.

Most CFS data, information, and knowledge holdings are not electronically accessible. In some cases, the information has not been digitized; in others, there is no infrastructure in place to enable access. The cost of digitization and infrastructure development can be prohibitive in the current fiscal environment. This is especially true for digitizing the very large collection of legacy data and documents. Without allocations of funds specifically targeted for digitization and infrastructure development, progress will continue at the current varied and limited rate.

Awareness of resources and costs associated with developing a K-If is essential to planning an initiative. A Federal Task Force on Digitization (1997) survey of digitization activities found that 33% of institutions spend less than $100 000 per year, 17% spend between $100 000 and $1 million, 10% spend more than $1 million, and 39% did not know how much was spent. The funding range was also highly variable, from a low of $450 to a high of $12 million.

An informal survey of CFS S&T network programs disclosed that $600 000 (8% of the total S&T operating budget, not including salaries) is currently being spent on S&T that is directly related to knowledge activities. Another $135 000 (not including salaries) is spent annually on the National Forestry Database. In 1995, a one-time investment of $1.8 million was made for the Common Office Environment. Although these ad hoc samples indicate that knowledge activities are being undertaken within the CFS and that they are financially supported, the total investment is not known.

The Information Highway Advisory Council (1995) suggested that government agencies could solicit competitive bids from the private sector for digitization initiatives. However, the private sector will not invest without adequate financial incentives. Survey results show that only 25% of federal institutions are involved in digitization partnership agreements. Currently, neither the regulatory environment nor the potential for revenue generation or cost recovery encourages such partnerships.

The continuing evolution of standards, network protocols, technological innovations, and new types of media demands that radical shifts be made in the ways we manage information and provide access to it. Although some responses to these changes can be accommodated through reallocating resources within existing appropriations, in many cases, additional funding will be required to ensure that the CFS continues to fulfill its mission and meet client and partners expectations in a knowledge-based economy.

The Federal Task Force on Digitization outlined a sequential funding strategy that could be adapted by the CFS to fund its digitization activities:

- Use available resources to absorb the costs of ongoing operations and practices for providing access to digitized information. Digitization must be recognized as essential to existing and planned programs. Funding of new programs should include specific allocations for digitization.
- Develop policies and guidelines that foster and facilitate partnerships and collaboration in order to limit agency costs and exploit private sector market responsiveness. Policies should provide flexibility for reinvesting revenues in digitization projects.
- Establish revolving funds so that repayable advances could be used to fund specific projects supportable by business plans.
- Collaborate with other agencies whenever there are complementary mandates and objectives. Collaboration could be extended to include program delivery.
- Join with education and awareness programs in the public and private sectors to develop expertise and to devise innovative funding solutions.
- Link digitization with other agency objectives such as youth employment and forest-sector competitiveness.
- Involve the private sector by developing mechanisms for joint investment, revenue sharing, and cost recovery. This enables the use of private sector expertise and provides a stream of revenue that could be reinvested.
- Use licensing agreements with the private sector as financial incentives for participation in digitization projects.
- Establish a dedicated fund to advance development and implementation of a CFS K-If. Without such a fund, the rate of advance of the CFS into the knowledge economy could be relatively slow and uneven.

Staffing

Staffing will be needed to develop and implement a CFS K-It. Staffing can be viewed from two perspectives, numbers and expertise. The Federal Task Force on Digitization (1997) found in a digitization survey that 19% of responding institutions assigned less than 1 FTE (full-time equivalent) to digitization, 17% assigned 1–5 FTEs, another 17% assigned more than 5 FTEs, while 46% did not know what staff was committed. Essentially, the human resource complement varies substantially from a low of 0.05 to 125 FTEs per year. No data are available for the level of CFS staffing associated with digitization activities.

The CFS recently underwent a 35% staff reduction. Although the total workload was also reduced, the latter was not proportional to the former. Some responsibilities are mandated and could not be dropped; some important programs could not be eliminated. Thus, the workload for many employees increased. Given a finite amount of time to accomplish their work, employees have had to devote less time to each activity. The availability of time has become a limiting factor in the ability of the CFS to undertake new initiatives or switch priorities. How quickly a task can be done is as important as how well it should be done. The accomplishment of one task may mean another task is not performed or not done as well as it should have been.

The challenge of staff time will have to be resolved if the CFS is to succeed in implementing a K-It. This may take the form of hiring additional staff, reassigning existing staff, or shifting (not adding) individual duties. Ad hoc efforts sandwiched between competing priorities cannot hope to succeed in an agency-wide initiative of this magnitude. Although much can be accomplished

with existing resources, commitment of staff to the K-It will be essential.

Scientists tend to be splitters (they emphasize differences), while systems analysts tend to be lumpers (they emphasize similarities). This is more than a simple difference of perspective. Each group has a lifetime of experience in using its approach; each has difficulty in adopting the other; few people appreciate both and can translate from one to the other. Neither perspective is sufficient for the success of an organization; both are necessary.

As a science organization, the majority of our expertise is not well suited to the systems thinking needed for implementing a K-It. Ecologists may be an exception to this generality because their domain rarely offers opportunities to isolate anything. In fact, a biologist, Ludwig Von Bertalanffy (1968), is credited with co-founding the general theory of systems. The CFS will have to identify a cadre of individuals who are capable of and comfortable with working in a holistic environment to form a core of expertise and leadership. These individuals should also understand the systems approach.

Knowledge Management

The CFS must evolve in order to fulfil its federal forestry mandate in the newly emerging knowledge economy. Just as businesses must manage inventories, assets, and products to remain competitive, the CFS will have to manage data, information, and knowledge to remain relevant. In the new paradigm, the CFS will need an infrastructure to acquire, synthesize, disseminate, and manage its knowledge assets.

There is a rapidly growing literature about the Information Highway that focuses on its underlying technology and the dissemination of content. These are two essential aspects of the CFS's K-If objectives. However, the amount of information exchanged is proportional to the amount produced and made available by the S&T networks and national forestry programs. Therefore, a third aspect of the CFS K-If is how to use information and communications technology to better manage the production of knowledge. Because most people have a general understanding of how a business is run, it is instructive to use a business analogy to describe the production of knowledge.

A business analogy

Businesses have well-developed systems and processes in place to manage their activities, without which they would not survive for long. Concepts used in the management of business processes and activities are shown in the left-hand column of **Table 6**, with comparable knowledge management concepts shown in the right-hand column.

The CFS uses well-developed processes and information systems to manage administrative matters, such as personnel, accounting, budgeting, facilities, and programs. However, its knowledge management processes and systems are minimal to nonexistent. For example, acquiring and storing data is normally left to individuals. Inadequate and inconsistent policies are in place concerning ownership or sharing of data or information. Few formal processes exist to inventory, manage, or preserve explicit or tacit knowledge assets. There are no mutually agreed interoperability protocols or metadata standards to facilitate data exchanges among domain-specific databases, information systems, and knowledge synthesis, making it difficult to produce integrated products. A CFS K-If would support efficient and effective knowledge management.

Another important shortcoming is the limited interaction among the many groups that produce knowledge. This results in duplication of effort, inefficient use of limited expertise, unnecessary expenditures, and sub-optimal accomplishments. It must be recognized, however, that interaction takes time, both to disseminate information and to assimilate it. And time may be the CFS's scarcest resource. A key objective of

Table 6. Concepts used in the management of business processes and activities and comparable ones that can be applied to knowledge processes.

Business concepts	Knowledge concepts
Supplier catalogues	Metadata directories
Purchasing	Information acquisition
Inventory	Data
Assets	Tacit knowledge, literature, databases
Plant	Laboratories, offices
Equipment	Information and communication systems
Production	Information production, knowledge synthesis
Products	Publications, systems, technology
Promotion	Communication
Market survey	Advisory groups
Marketing	Information adaptation
Sales	Licensing
Distribution	Dissemination
Contracts	Intellectual property
Profit	Understanding, learning

the K-If will be to facilitate and enhance the capacity for communication among knowledge producers and users.

Knowledge production

Because forestry issues are becoming increasingly complex, the CFS needs to find ways to use information and communication technologies to synthesize new knowledge beyond what is possible with traditional methods. Processing information on the World Wide Web involves five stages of progressive complexity:

- Descriptive: general information about an organization (e.g., the CFS home page).
- Static: information about a subject (e.g., *The State of Canada's Forests*).
- Updated: periodically updated reports and data (e.g., the National Forestry Database).
- Dynamic: continuously updated data and information (e.g., fire management systems).
- Interactive: user-created analyses of issue-specific data (e.g., the National Forest Information System).

Organizations normally start at the lowest level in processing information on the Web and evolve through successive stages by adding more complex information while retaining existing material. From an organizational perspective, increasing levels of information complexity imply additional resources, changing objectives, and different policy considerations. Higher levels of information complexity provide clients with more sophisticated access to content, search and retrieval, and analysis capabilities, and represent an increase in the cost and the value of information to providers and users, respectively.

Table 7 lists the attributes (type of user, the information content, data accessibility, search capability, and user interactivity) of each stage of using the World Wide Web to produce and disseminate knowledge from a user's perspective.

The main users of descriptive-stage sites are members of the general public who may be randomly "surfing" the Net or looking for specific information when they find a site for the first time. The content is primarily descriptive—about the organization and its programs. Data are not accessible. Searching involves the use of tools provided by Web technology The user can only download information. Users are unlikely to visit a descriptive-stage site more than once due to the limited information available. Some CFS Web sites are still primarily at the descriptive stage.

Static-stage users are those who need general information about a subject, for example, students, the media, and politicians. The static stage contains fixed information, such as reports, publications, and limited amounts of text-based data. This stage usually includes site or domain search capability and user feedback. Most organizations evolve to this stage fairly rapidly after establishing a presence through the descriptive stage. Many CFS Web sites are at this stage.

The third stage involves data and information that is periodically updated (annually, quarterly, monthly). Users at this level are likely to be domain-specific stakeholders and professionals who need current in-depth information. At the this stage, users can download

Table 7. Five stages and their attributes of using the World Wide Web to produce and disseminate knowledge–a user's perspective.

Stage	Users	Content	Data	Search capability	User
Descriptive	Public	Program descriptions	None	World Wide Web	Accesses information
Static	Students, media, politicians	Reports, publications, text-based data	Static data	Site/domain	Gives feedback
Updated	Stakeholders, professionals	Inventories, statistics, numerical databases	Updated databases	Organizational directories, libraries	Joins discussion groups, e-mails, tabulates data, writes reports
Dynamic	Managers, specialists, technicians	Information systems	Multiple-linked databases	Multiple agencies, national digital libraries	Orders services, manipulates data, produces information
Interactive	Scientists, analysts, economists	Decision-support systems	Custom databases	Intelligent and plain language searches	Analyzes data, runs a model at a remote location, synthesizes knowledge

numerical data to perform custom calculations. More comprehensive custom-built search engines can access organizational directories and libraries. The level of interactivity also increases to include e-mail connectivity, discussion groups, and an ability to perform elementary statistical analyses and to produce reports. Development of this stage of information access is well under way at the CFS, with a few sites currently available on the Web.

The fourth stage involves information systems that continuously update data and information, such as fire-danger and fire-activity systems. This type of technical information is needed by specialists and managers to plan and implement daily operations. Such systems are typically highly or fully automated to meet challenging, real-time processing demands. They also usually involve interconnectivity among multiple databases. Search capabilities may include multiple agencies and national digital libraries. Users can order products and services, manipulate data, and produce their own custom information. A few CFS sites currently provide dynamic information.

The interactive stage is the most complex level of Web-based knowledge production. This is usually used by those who need to synthesize knowledge, such as scientists, policy analysts, and economists. This stage provides users with an ability to create customized databases. Search capability may include artificial intelligence and plain language. Users can analyze data, run models remotely, and synthesize new knowledge. The CFS is currently developing systems that will eventually enable interactive Web-based knowledge synthesis.

Table 8 lists the attributes of the five stages of Web-based information processing from a provider's perspective. Attributes are time and staff needed to implement a site, type of equipment, cost, site objectives, and policy considerations.

It requires relatively little time and staff to develop a descriptive agency-wide Web site. Equipment needs and costs are nominal. The focus is to establish a presence on the Web and promote the organization. Policy concerns center on identity and communications issues. Although of limited usefulness, descriptive sites are a key first step in acquiring organizational skills and experience in creating Web pages.

Static sites require somewhat more time and staff to develop than descriptive ones. They usually involve planning and organizing, digitizing legacy document collections, and converting them to HTML format. A standard PC is normally adequate to manage a static information site. The budget for such sites may be significant from a project perspective, but are not significant at the organizational level. The primary objective of such sites is to provide access to digitized information. Key policy considerations involve publication and authentication issues.

Updated sites require more resources for development and continuing maintenance. Because of content complexity and the need for staff interactivity, a Local Area Network (LAN) is required to support this type of site. Budgets may be in the order of a few hundred thousand dollars. Such sites are typically used to support monitoring and marketing functions. Key policy issues include access rights and limitations, quality assurance and control, and cost recovery for value-added information.

Dynamic sites continue the trend of increasing the need for resources for development and maintenance.

Table 8. Five stages and their attributes of using the World Wide Web to produce knowledge–a provider's perspective.

Stage	Time	Staff	Equipment	Cost($)	Site objectives	Policy concerns
Descriptive	1-2 mo	Casual	PC directory 50 -100KB	5 000–10 000	Promote organization, establish a presence	Identity, communication
Static	2-4 mo	Part-time	PC 1-2MB	50 000–100 000	Provide access to digitized information	Publication, authentication
Updated	6-12 mo	Half-time	LAN 100–500MB	100 000–300 000	Support monitoring and marketing functions	Access rights, quality assurance and control, cost recovery
Dynamic	1-2 yr	Full time	Server 10–20GB	500 000–1 million	Provide technical support, share data and information	Interoperability standards, partnerships
Interactive	3-5 yr	Team	System 100–500GB	5 - 10 million	Support knowledge synthesis, policy development, and sector competitiveness	Intellectual property

Such sites are likely to require their own server, work stations, and data storage capacity beyond that available with PCs in a LAN. Costs may exceed a half a million dollars. These sites provide technical support for real-time operations. At this level, interoperability standards and partnerships are essential.

Interactive sites are the most demanding in terms of resources and equipment. They will require full-time teams for development and maintenance. They are likely to take several years to develop and cost in the order of $5–$10 million. Substantial custom in-house systems will have to be developed to support interactive sites. These sites can ultimately achieve the objectives of supporting knowledge synthesis and policy development and fostering sector competitiveness.

No Web site is likely to function entirely within one information stage. For example, one can conceive of an "ask the expert" function that is highly interactive from a user perspective and that requires only one staff person with extensive links to information sources. Furthermore, as use of the Web evolves through various stages, there remains a need to retain information provided in earlier stages. Thus, advanced sites will continue to provide descriptive information in "about" pages, access to reports through "library" searches, and updated information in a "what's new" section.

Although the five stages are presented sequentially, one or more stages may be skipped when developing a Web-based information system. Also, most of the costs and resources relate to the development of the first system for any stage. For subsequent systems one will be able to substantially leverage existing infrastructure and experience, such that costs and staff requirements could be reduced by a factor of 2 to 5.

Current activities

Most of the current CFS presence on the World Wide Web involves passively providing public access to information. Although this is an early stage in Web-based information processing, it is an essential learning experience. The CFS presence on the Web is provided by six sites—Headquarters and the five forestry centers. The sites are partially linked and have some similarities. They are, however, independent, and each is organized differently. At present, overall CFS information can only be accessed by connecting to each site individually.

CFS efforts to establish a presence on the World Wide Web have been characterized by a flurry of activity. Communication among people working on individual projects is often limited, with efforts to launch projects happening more or less on their own. Simply finding all the activity for the purpose of this report was challenging; searches revealed endless possibilities or failed to find something known to exist. This lack of coordination and communication in CFS Web activities has led to some duplication, wasted effort, inconsistent results, counterproductive objectives, and lack of agency recognition. These problems are not yet significant, but will become so if they are not addressed soon.

On the positive side, a significant cadre of CFS expertise is developing that will ultimately lead to meaningful discussions when the time comes to put everything together. Many current CFS activities have a presence on World Wide Web sites. More are under development. Existing knowledge-related activities form a broad-based foundation that could support the development of a CFS K-If. Some patterns are apparent from reviewing activities. Much work is already underway at the working level and among front-line managers (see Appendix 2). The collective strength of this grassroots effort may be sufficient to drive a CFS K-It; it will certainly provide substantial support for it. The objectives of most existing knowledge activities relate to transforming data into information and synthesized knowledge. They tend to go beyond simply disseminating content, which is the focus of most initiatives outside the CFS. This suggests a "niche," where CFS experience and strengths could be used to add significant value to the headlong rush to develop a Canadian information society.

> *We have suddenly arrived at a stage where, due to wave after wave of breakthroughs in computer and communications technology, the means exist to store, process, and disseminate wisdom on an incomparably vaster scale than was possible before.*
>
> —Taichi Sakaiya, *The Knowledge-Value Revolution* (1991)

The discussion of a CFS knowledge infrastructure (K-If) presented in Part 2 follows the evolution of the knowledge management process—from data through information to knowledge. Data management, which is associated with the computer revolution, is the best understood part of the process. Over the last two decades, the focus in knowledge management has gradually shifted to the content or meaning that is carried by data, in other words, the information. Understanding what information is and how it can be used is important to understanding what the information society is all about and the role of the CFS in it. Although the concept of knowledge has been around for 2500 years, it has only recently emerged from the cloistered environments of philosophy and science and entered the worlds of business and policy. Hence, definitions and understanding of knowledge are very much in the exploratory stages. Part 2 ends with a proposed framework for the infrastructure and a discussion of the program elements that will be needed to develop it.

Data Management

> *It is a capital mistake to theorize before one has data.*
>
> —Sherlock Holmes in "A Scandal in Bohemia" (1892) by Sir Arthur Conan Doyle

Standards

Data standards are detailed technical guidelines that are used to establish uniformity in a digital environment. *De jure* standards are created through formal national and international processes based on committees of experts; *de facto* standards are conferred by normative use in the marketplace. The government does not, contrary to popular belief, develop data standards. It does define data elements needed for community-wide use, such as e-mail naming conventions for departments.

Rapidly emerging technologies, coupled with numerous proposed standards, and an increasing number of stakeholders in the standards and user communities have created a standards crisis in informatics. The Federal Task Force on Digitization (1997) identified 62 standards currently in use for data transfer, text, graphics, sound, multimedia, searching, location, and metadata. Although some were widely used (30% or more of survey responses), there was a significant diversity of "other" responses. This proliferation makes it difficult to identify what might be considered best practice.

Existing organizations and processes that are used to develop standards are generally recognized as too slow to be effective. New processes and organizations, mostly within the Internet community and through industry consortia, are providing a framework for new networking and digitization standards development. The challenge for all government institutions is to ensure that current and future infrastructures support the varying mandates of federal institutions.

All standards have strengths and weaknesses. Each standard has a use and a user community, and no single standard or set of standards can satisfy the requirements of all users, in all places, at all times. Well-chosen standards facilitate interoperability; a lack of standards or poorly chosen ones inhibit interoperability.

Appropriate standards and best practices can assist institutions in balancing the need to meet diverse organizational objectives while maintaining adequate interoperability to disseminate or exchange digitized information. Standards should be evaluated based on their ability to balance these two objectives. The CFS will have to rely on sharing technical information and work cooperatively with NRCan and its forestry partners to select interoperability standards that achieve this balance.

Several standards need to be selected: metadata (description), locator (address), navigation (search), data transfer (retrieve), document (text), spatial (georeferenced), audio (sound), image (still, moving, 3D), and directory (lists) standards. In most cases, more than one standard will be needed. For example, at least eight

data transfer standards are currently used by the CFS: Gopher, HyperText Transfer Protocol (HTTP), Multipurpose Internet Mail Extensions (MIME), Simple Mail Transfer Protocol (SMTP), X.400 Mail, Transport Control Protocol/Internet Protocol (TCP/IP), Telnet, and File Transfer Protocol (FTP).

Metadata

A digital library may contain a few thousand to a few million digital objects. The objects, which can contain many types of data (numeric, text, graphic, audio) are often stored over a network of dispersed repositories. Metadata are vital to a digital library. They are more than the digital equivalent of a traditional card catalogue. Metadata are necessary to identify not only bibliographic information such as title, creator, date, and location, but also properties, such as type of data, format, processor, rights information, use imitations, and authentication.

Metadata files may contain from a few elements (simple text files) to a few hundred attributes (satellite images). Although metadata standards are ideally independent of the data that they describe, this is only achievable within types of data; no single metadata structure is appropriate for all types of data. Of primary concern to the CFS are metadata standards for thematic and spatial data.

The Government Information Locator Service (GILS) is an electronic metadata standard that can identify information holdings throughout the government, describe the information available in these holdings, and provide assistance in obtaining the information. GILS is essentially a pointer that can lead a user to information. For electronic information, GILS directories include an electronic link to the resource. GILS is a text-based keyword standard that is well-suited to documents, databases, catalogues, and directories. GILS has been adopted by the Treasury Board and is recommended for use by all government departments. It is based on internationally accepted (ISO, International Organization for Standardization) non-proprietary standards. Should the CFS choose another standard, it should be GILS-compliant.

Metadata standards for spatial data are considerably more complex than those for thematic data. Although spatial data standards could be used for spatially referenced thematic data, they are far more complex and cumbersome to use than the GILS standard. They contain masses of details that are important to accurately georeferencing spatial data, but that are unnecessary for documents. The additional complexity would discourage use by database managers and clients who simply want to find a particular document.

Data from Partnerships

The CFS depends on land-management agencies to provide data about the state of Canada's forests and forest activities. The CFS cannot publicly disseminate the data from partners without negotiating formal agreements concerning what may be disseminated, to whom, and in what format. Some data are confidential as individual elements; some could provide a competitive advantage; and some could impact legal proceedings.

In addition, each agency has individual policies on data access. Developing a national consensus on dissemination will thus be a challenging and lengthy process. The type, amount, and level of detail that can be publicly or internally disseminated will likely vary from agency to agency. Whatever the difficulties, the CFS must honor all formal and informal agreements with partners and maintain the atmosphere of trust that has been developed over a long period of time.

Some principles of data partnerships include:

- Data should be collected once, closest to the source, in the most efficient way possible.
- Data infrastructures should facilitate vertical and horizontal integration.
- Data should be as seamless as possible across jurisdictional boundaries.
- Open international standards should be used to facilitate interoperability across databases.
- Partners should contribute equitably to the costs of collecting and managing data.
- Partners should equitably share revenues generated from jointly produced information.
- Partners should have access to all information for their own use and dissemination.
- Agreements should be negotiated on a bilateral or multilateral basis.
- Agreements must reflect differing federal and provincial mandates.
- Agreements on access and use should be harmonised.
- Partnerships should be open to participation of all interested stakeholders.

Information Management

The information we have is not what we want.
The information we want is not what we need.
The information we need is not available.

—John Peers, *1,001 Logical Laws* (1992)

It is useful to explain the purpose of information management from a CFS perspective. On one side of the process is a set of complex issues that the CFS is mandated to address, such as the criteria and indicators of sustainable forest management, climate change, and the National Forest Strategy (**Figure 4**). On the other side are a number of distributed databases, each of which contains some of the data that are needed to analyze each issue. However, to analyze any issue, data are needed from several databases, most of which have been produced with different systems and are stored in different formats.

The purpose of the National Forest Information System is to access all databases needed for an issue, integrate them into a coherent whole, and enable analysis and reporting on issues as needed. The Internet is used to connect the NFIS to the world. This section will describe the inner workings of the flow of information from its source to eventual use.

Information Flow

Two strengths of the CFS are its formidable capacity for forestry science and technology and its corporate capacity for forestry policy formulation and issue response. Science focuses on creating new knowledge through carefully controlled experiments. Policy focuses on synthesizing knowledge from a broad range of information sources. Currently, there are two categories of science and policy information users, national and local/regional. National users are typically interested in broadly based issue-oriented information to support policy formulation, decision-making at the program level, or public information. Examples include the criteria and indicators of sustainable forest management, *The State of Canada's Forests* report, and climate change. Local and regional clients are primarily interested in operational resource management questions. Examples include decision-support models for fire management, integrated pest management approaches, and improved methods in biotechnology. Reconciling the information requirements of these two disparate groups of clients is a challenge confronting the CFS.

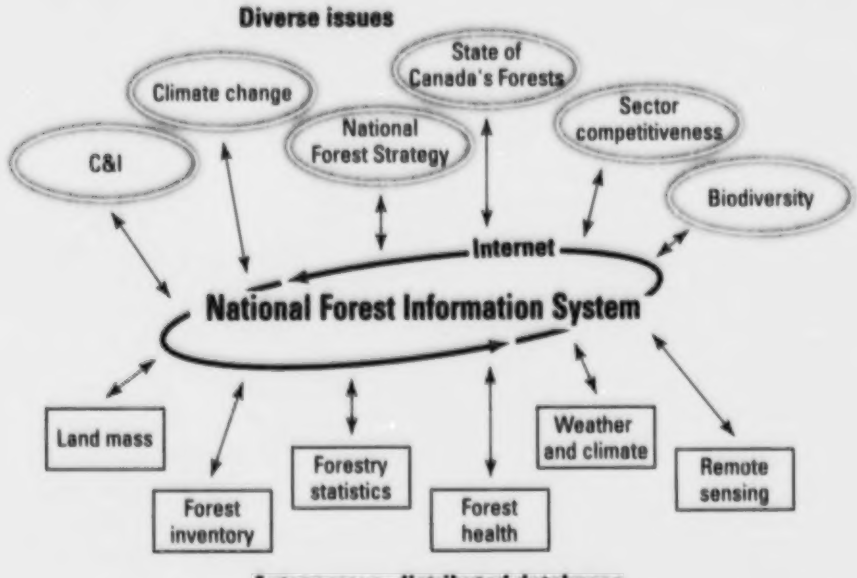

Figure 4. The National Forestry Information System links many databases to various issues through the Internet (C&I, criteria and indicators of sustainable forest management).

Vertical information flow

Transforming information from lower levels of meaning and organization to higher (e.g., from data into information, from scientific studies into policy formulation, from local reports into national statistics) is generally referred to as the vertical integration of information. It poses several challenges for the CFS. Vertical information flow requires

- Greater levels of social, economic, and cultural information at higher organizational levels.
- A good understanding of how science results are incorporated into policies and issues.
- An ability to incorporate detailed information into broad issues.
- Databases with the right information to address rapidly evolving issues.

The K-If should incorporate more than quantitative analyses of data and information. The CFS information flow model must therefore be sufficiently robust to include other forms of information processing. For example, although human reasoning is complex and incompletely understood, the same linear flow model should be able to describe this subjective process with slightly different terminology. Expert systems, which function in the grey zone between quantitative analysis and subjective reasoning, should also be describable with a similar approach.

In a decision-support system (**Figure 5a**), content begins as raw data. It flows through a series of processes in which it is organized into a database, translated into information, synthesized into knowledge, and used to support a decision. The processes that control the flow between stages are called data acquisition, information systems, decision-support systems, and application. Although decision-support systems often acquire data from many sources, they are typically related to a specific domain. These systems usually provide features such as analysis tools, process models, search and query capability, report generation, and graphic outputs. Executive information systems specialize in high-level information; they identify exceptions and provide drill-down capability for additional detail.

Human reasoning (**Figure 5b**) lies at the opposite end of the information management spectrum. Although a very complex subject, it can be modeled as a sequential flow-through system similar to the decision-support system in Figure 5a. An individual begins with a search of the literature and libraries to determine what

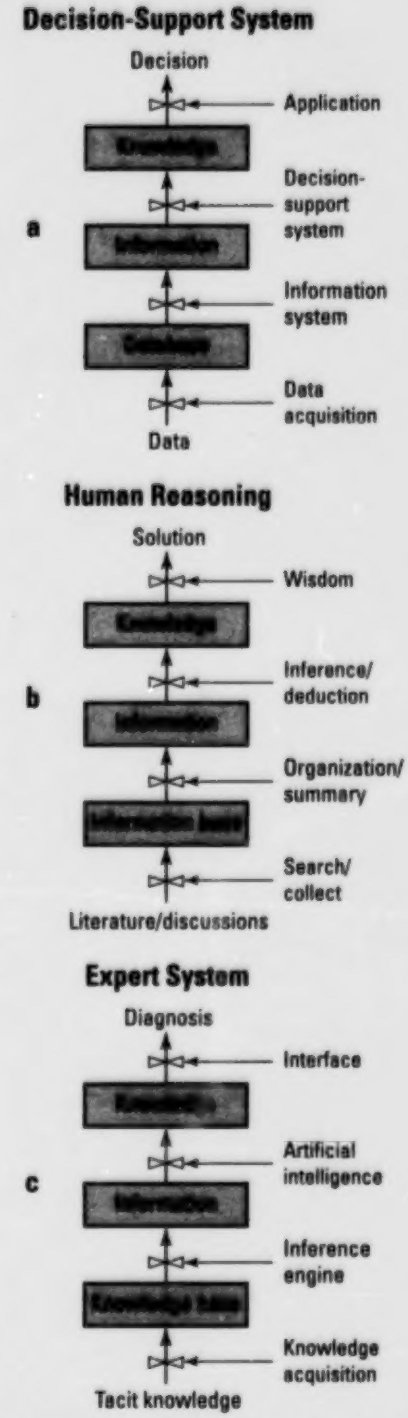

Figure 5. Vertical flow of information for (**a**) a decision-support system, (**b**) human reasoning, and (**c**) an expert system.

is known about a subject; organizes and summarizes relevant information into an information base; and then synthesizes knowledge through inference and deduction. Wisdom, which can be defined as the correct application of knowledge, is used to solve the original problem that started the process. Although human reasoning is primarily subjective, the scientific method incorporates a significant analytical component in the presentation of proof to support a hypothesis.

Expert systems (**Figure** 5c) are a relatively recent technology lying between quantitative analysis and subjective reasoning. Developing an expert system begins by formally acquiring tacit knowledge elicited from an expert and coding it into facts and decision rules that are stored in a knowledge base. A heuristic inference engine uses a set of if/then/else rules to search the knowledge base to draw conclusions about a set of inputs for specific cases. Artificial intelligence processors may provide limited capability to synthesize new knowledge. Finally, a user interface produces a diagnosis of the most likely causes of the observed inputs. Although based on tacit knowledge, empirical rules, and heuristic techniques, information processing is essentially quantitative.

Horizontal information flow

A key element of the horizontal flow of information is interoperability, the ability to integrate data and

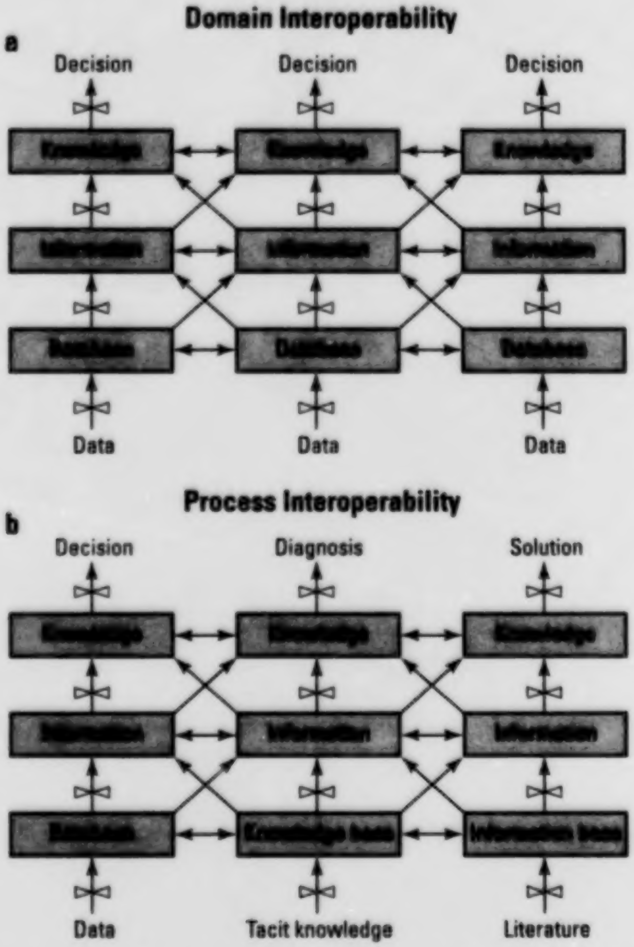

Figure 6. Interoperability enables the horizontal flow of knowledge by (**a**) linking a set of domain-specific decision-support systems and (**b**) crossing process boundaries.

information across domains. The primary purpose of cross-domain interoperability is the capability to synthesize new kinds of information and knowledge from multiple data sources. This is essential to addressing complex issues, such as sustainable forest management and climate change. Interoperability requires integration not only across traditional forestry disciplines such as forest management, fire research, and forest health, but also across new domains, such as economics, culture, and international agreements.

Integrating information horizontally poses several challenges for the CFS. It requires

- Metadata and interoperability standards.
- Standard platforms and software systems.
- Knowledge of and access to external databases.
- Interdisciplinary expertise.
- Maintenance of the scientific integrity of different databases.
- Good analytical and modeling capabilities.

In its most elemental form, interoperability is a framework that links a set of domain-specific decision-support systems (**Figure 6a**). Thus, interoperability standards would enable data from different databases, such as forest inventory, forest harvesting, forest fire, and forest health databases, to be integrated into a single database. This could be transformed into information in the form of a map of total forest disturbance. Alternatively, a single decision about sustainable forestry could be supported by data and information drawn from many different sources.

Domain-specific processes remain intact, as do their data sources and information outputs. Forest fire models are not the same as those used by insect and disease surveys or forest inventory. Management of each function lies within the domain of a community of experts, specialists, technicians, and practitioners. However, domain-specific decision-support systems would benefit by being able to draw from a wider range of data and information.

Even the most advanced artificial intelligence processor cannot truly synthesize new knowledge. It can only process data to the extent that it has been programmed, which is limited by what is already known. Thus, knowledge synthesis is essentially a subjective human activity that is supported by objective information systems. Therefore, interoperability must also be able to support human reasoning by interacting with people-based knowledge activities (**Figure 6b**).

Relatively little attention has been paid to the zone between human reasoning and analytical information systems. A well-designed K-If should take advantage of expert-systems technology, such as those that do intelligent searches, disease diagnosis, and plant and animal species identification. As an interim step, the CFS K-If could incorporate an "expert" (or someone with extensive organizational contacts) to respond to enquiries posed by the general public.

Digital Libraries

The ultimate application of interoperability is through digital libraries. A digital library is a collection of very large numbers of digital objects, comprising all types of material and media that are stored and accessible over national computer networks. Whether a digital library links centralized or distributed sites, the concepts are the same. An information architecture for a digital library was developed by Arms et al. (1997). The purpose of the architecture is to represent the richness and variety of library information, using the building blocks of a digital library system.

A digital object is a way of structuring information in digital form, some of which may be associated metadata, and includes a unique identifier called a handle. Although all digital objects have the same basic form (content plus metadata), material in a digital library is far from simple. It can be divided into categories, such as texts with SGML mark-up, World Wide Web objects, computer programs, and digitized radio programs. Within each category, rules and conventions describe how to access and organize the information. The rules describe the digital objects that are used to represent material in the library, how each is represented, how they are grouped into sets of digital objects, the internal structure of each digital object, the associated metadata, and the conventions for naming the digital objects. A single work may have many parts, a complex internal structure, and several arbitrary relationships to other works.

A user interface that is aware of the rules and conventions applying to certain categories of information is able to interpret the structure of the set of digital objects. Complex information can be presented without the user having any knowledge of the complexity. Since the user interface recognizes how material is represented, it can provide unsophisticated users with flexible access to rich and complicated information.

The digital library framework enables the accessing of information from many different computer systems. The framework comprises the user interface, the repository system, the handle system, and the search system. They run on a variety of computer systems connected by a computer network, such as the Internet.

There are two user interfaces: one interface for library users and one for librarians and system administrators who manage the collections. Each user interface has a standard Internet browser for the actual interactions with the user. This browser connects to a client server, which functions as an intermediary between the browser and the other parts of the system. The client server allows the user to decide where to search and what to retrieve. It interprets information structured as digital objects; negotiates terms and conditions; manages relationships between digital objects; remembers the state of the interaction; and converts among the protocols used by the various parts of the system.

Repositories store and manage digital objects and other information. A large digital library may have many repositories of various types, such as information holdings, legacy databases, and Web servers. A Repository Access Protocol (RAP) provides an interface to the repositories. Features of the RAP are explicit recognition of rights and permissions that need to be satisfied before a client can access a digital object, support for a very general range of dissemination of digital objects, and an open architecture with well-defined interfaces.

Handles are general purpose identifiers that can be used to identify Internet resources, such as digital objects, over long periods of time and to manage materials stored in any repository or database. The handle system developed by the Corporation for National Research Initiatives in Reston, Virginia, is a computer system that provides a distributed directory service for identifiers (handles) for Internet resources (see Arms et al. 1997). When used with the repository, the handle system receives as input a handle for a digital object and returns the identifier of the repository where the object is stored.

The design of the digital library system assumes that there will be many indexes and catalogues that can be searched to discover information before retrieving it from a repository. These indexes may be independently managed and support a wide range of protocols. The search system for a digital library must be independent of any specific search system. A generic prototype search system is currently in use at the Library of Congress.

Knowledge Management

When the Sphinx was built, and the Roman roads and the London Bridge and the Panama Canal and the New York subways, there had to be in every instance a part of the citizenry whose professional job it was to relate the technology to the objectives, the social environment, the available resources, the time constraints, and the economics.

—Simon Ramo, *Cure for Chaos* (1969)

Humans have naturally "managed" knowledge since the dawn of civilization. For 6000 years, writing has provided a means to record knowledge and to govern cities and empires. The printing press increased the availability of knowledge by orders of magnitude, leading to the Age of Discovery, the Reformation, and the birth of science. Today, we are beginning to systematically explore and understand how knowledge is created and how to organize and manage it. In this section, four aspects of knowledge management are examined: knowledge flow, synthesis, preservation, and exchange.

Knowledge Flow

At any moment of time there is a level of existing knowledge; during any interval of time there is a flow of knowledge (Stewart 1997).

An overview of the processes that control the inputs and outputs to knowledge management—synthesis and preservation—is given in **Figure** 7. The flow of knowledge begins in an infinite source that contains all possible knowledge that could be discovered. Knowledge flows into a reservoir of existing knowledge. The rate of flow into existing knowledge is controlled by scientific discoveries, technological development, and cultural experience, all of which are affected by the level of existing knowledge through a feedback loop. There is also a flow from existing knowledge into an infinite sink of lost knowledge. This flow rate is controlled by social decay, technological obsolescence, and institutional reductions. The level of existing knowledge at any moment is based on the difference between the inflow and outflow rates over time.

In the present context, two aspects of existing knowledge are relevant—science and technology. Traditionally, models have shown science as a precursor to technology; this is no longer necessarily how it is viewed. Some scientific knowledge enables new technologies, while some technologies enable new kinds of science. Science increases our understanding of natural and

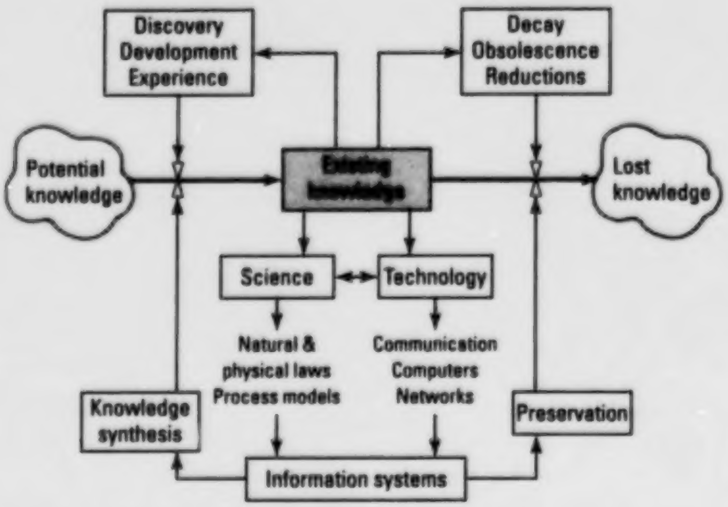

Figure 7. Processes that influence the inward and outward flow of knowledge.

physical laws which, in turn, leads to process-based models of various phenomena. Communication, computer, and network technologies are relevant in the present context. Collectively, science and technology support development of information systems.

Information systems are used to support the synthesis of new knowledge and, hence increase the rate of flow into existing knowledge. They are also used to support the preservation of knowledge and, hence, decrease the rate of knowledge loss, particularly that resulting from institutional reductions.

Knowledge Synthesis

In designing a CFS K-If, it is important to understand how people and systems interact as raw data is transformed into knowledge. **Figure 8** outlines the principal elements of knowledge synthesis. People, working in organizations, use systems that are supported by technology to produce knowledge. Each process comprises several components (e.g., people analyze, reason, and decide). Knowledge synthesis flows through several stages; it starts with acquiring data and ends with disseminating what has been produced. Each stage of processing transforms content from a lower to a higher, more valuable form.

In **Figure 9** the outline presented in Figure 8 is expanded to include the context within which knowledge synthesis is undertaken. When a problem or issue arises, a person begins searching for existing knowledge, information, or data related to the problem. The search results in a flow of relevant content from existing knowledge into a knowledge, information, or data base. The search is likely to be supported by information systems that contain relevant content or that can search and retrieve content from external sources.

If existing knowledge is adequate or there is insufficient time for further activity, the knowledge is applied to solving the problem and the process stops. If existing knowledge is inadequate and there is sufficient time for additional activity, knowledge synthesis is initiated. This results in a flow of relevant content from the infinite source of potential knowledge into new knowledge that is then applied to the problem. New knowledge is also added to existing knowledge for future use. Note that the search for existing knowledge occurs before knowledge synthesis starts.

The left-hand column of Figure 9 lists six processes related to knowledge synthesis—drivers, organization, people, information, systems, and technology. It is important to understand the differences between the processes and to keep the processes distinct as information flows through various stages.

Drivers are what make knowledge synthesis go. They are external to the system, part of the environment or context that surrounds knowledge synthesis. In this model, knowledge synthesis begins when a problem or issue arises; it is complete when a solution is found or a decision is made. The other key external

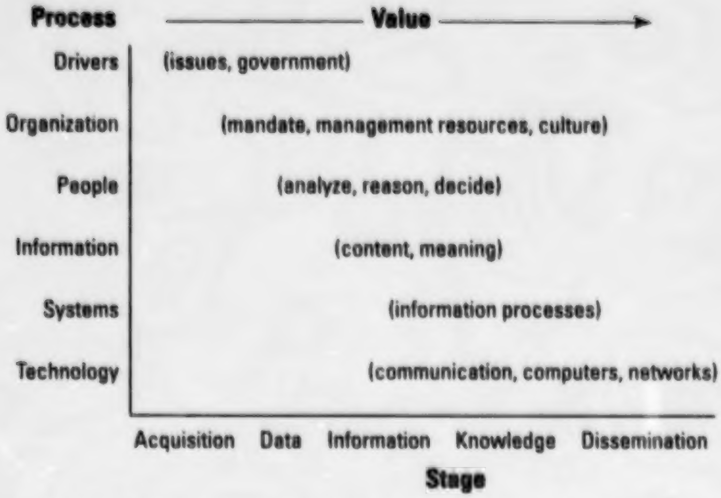

Figure 8. Processes and stages associated with knowledge synthesis. (Arrow indicates a flow from lower to higher knowledge value.)

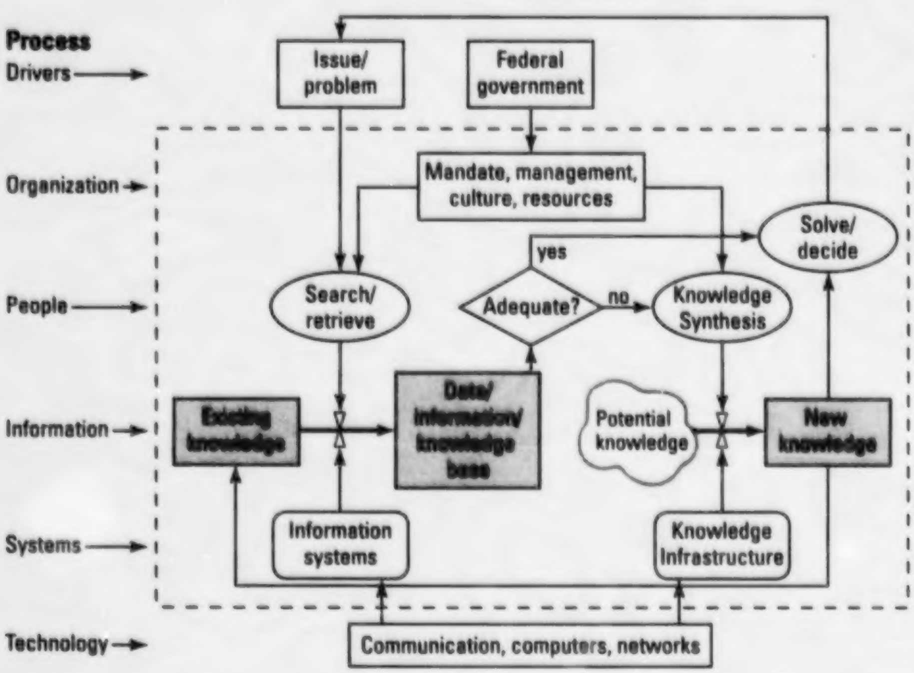

Figure 9. Flow of knowledge in relation to the context for knowledge synthesis.

driver is the federal government, which provides an organizational mandate, policies, and resources.

The second process, the organization, including its mandate, management structure, culture and resources, affects every aspect of knowledge synthesis. For example, the organization establishes objectives, policy guidelines, and deadlines for knowledge synthesis and allocates resources to knowledge management activities. The third process is what people do when they synthesize

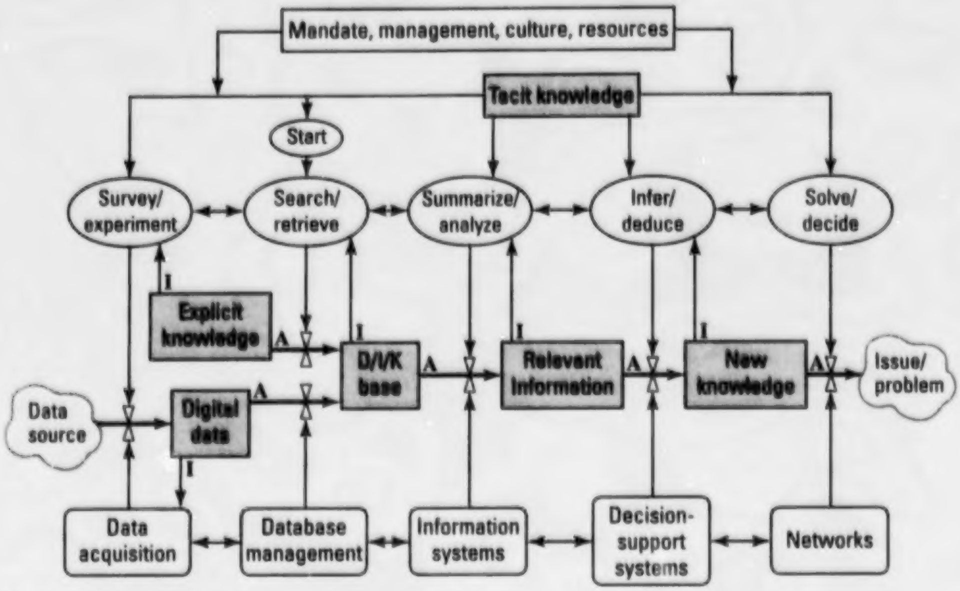

Figure 10. Knowledge synthesis.

knowledge. Since problems and issues are an essentially human construct, human activity is key to knowledge synthesis. People formulate the problem, decide what to do, do it, evaluate the results, go back or move forward in the sequence, and terminate the process.

The information process refers to the knowledge assembly line, the flow from raw material to finished product. It is important to distinguish between the actual content and the information processes that transform the content from one stage to the next. The fifth process is systems, the information management processes used to transform the content through the various stages. These have been previously discussed in some detail. The sixth process, technology, another external component in this model, supports every aspect of knowledge synthesis by providing the technical means to develop and operate information systems.

Figure 10 expands the simple linear flow of knowledge by incorporating all key components of the process, including recursive flow. This model incorporates six types of knowledge in four sequential stages. It indicates the specific human activities and systems associated with each stage of the transformation of data into knowledge.

The process starts with a decision to initiate knowledge synthesis. This decision stems from an issue or problem (Figure 9). It is affected by organizational constraints and responsibilities as well as the tacit knowledge of the decision makers. The first step is to search existing knowledge to determine whether or not adequate information already exists. As shown in Figure 9, the "yes" branch goes directly to application and terminates knowledge synthesis. Figure 10 addresses the case where existing information is inadequate and there is time and resources to continue—the "no" branch of the original search.

There are some overarching elements in the model. Information flow is recursive; at any stage, if the content is inadequate(I) and time and resources are available, the process returns to the previous stage to obtain more information. If the content is adequate (**A**) or time and resources are not available, the process advances to the next stage. Both human activity ("Survey/experiment...") and information systems ("Data acquisition...") flow both ways as the process cycles.

In most cases, existing, explicit knowledge may be adequate but it needs to be adapted to the issue at hand. If so, the process advances to the data, information, and knowledge (D/I/K) base. In some cases, the information gap is judged to be sufficient to require a survey or research study to generate additional data. Data acquisition and digitization generate digital data, which are transformed and added to the D/I/K base.

The content is then analyzed and summarized with the support of information systems. In the next stage,

the analyst infers or deduces new knowledge related to a specific issue, possibly aided by a decision-support system. This stage represents the closest link to the issue and is the most likely stage for deciding whether to return to a previous stage or terminate the process. That decision involves the adequacy of the knowledge, the importance of the issue driving the search, and the time and resources available for further examination.

Knowledge Preservation

From a preservation perspective, digital knowledge has one major characteristic in common with knowledge in traditional media. Both can be lost—through lack of storage space, moves in location, staff retirements or departures, lack of interest from new personnel, project termination, location closure, or simply by accident. A negative change in personnel, programming, or the work environment usually results in a notably greater loss of knowledge than a positive one.

Some preservation characteristics of digital knowledge are unique. It requires far less storage space than knowledge in traditional format. It is sensitive to permanent damage. To know how to access digital knowledge, one needs metadata. Digital knowledge is also inextricably linked to the software and hardware that created it. The long-term integrity of electronic storage media requires that digital resources be catalogued, maintained, and migrated to new technologies as they become widely used.

The Federal Task force on Digitization (1997) proposed a two-stage process for ensuring the preservation and accessibility of digital resources over time. The data, information, and knowledge should remain with the organization that creates or manages them for as long as they are actively used or required; after that, they should be preserved by the National Archives or National Library, as appropriate.

Processes are in place to preserve CFS records, based on federal government records management policies. Yet, the CFS has no preservation policies in place for its far more valuable and extensive scientific holdings, whether they are in traditional or digitized media. The CFS has a long tradition of allowing scientists considerable freedom in choosing research problems. This inhibits preservation, as succeeding scientists are unlikely to have the same scientific interests as their predecessors. They are also unlikely to be motivated to preserve past data unless they are potentially useful for anticipated future research. The same can be said of new managers and records from old programs.

Currently, preservation in the CFS depends on ad hoc individual initiatives. The consequence is that much invaluable data, information, and knowledge has been and continues to be irretrievably lost. An important part of the CFS knowledge infrastructure will be the development and implementation of processes to manage and preserve knowledge assets

Knowledge loss also occurs through the departure of skilled and experienced people from the organization after many years of service. In a science-based organization, people are the key knowledge resource. The CFS should establish on-going knowledge engineering techniques to capture and formally represent tacit knowledge and develop processes to capture the experience of departing scientists.

Knowledge Exchange

The knowledge synthesis model focuses on producing knowledge and knowledge processes from an organizational perspective. It assumes that the organizational framework and resulting activities are developed with resources provided by a central decision-making body. External linkages and partnerships encompassing the framework create an extended organization. Knowledge synthesis is an essential precursor to exchanging knowledge because the amount of knowledge that can be exchanged among organizations partially depends on the amount produced.

The basic building block of a knowledge exchange model is shown in **Figure 11**. All the components of knowledge production and processes are assumed to exist within the CFS. The amount of knowledge that flows out from the CFS or one of its branches depends on two factors, the quantity of knowledge produced and the "regulators" that control the flow rate. Regulators can be thought of as valves that open and close in accordance with organizational and external "settings." Thus, they can enhance or inhibit the flow of knowledge. The CFS should encourage a shift from regulators that limit the flow to those that enhance it. Examples of flow regulators are policies, mandates, perceived benefits, information attributes, technology, and infrastructure.

Figure 12 shows the exchange of knowledge between two agencies or branches. As in the previous model, each agency produces knowledge and makes

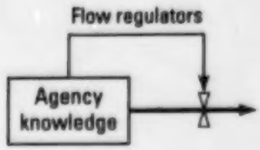

Figure 11. Knowledge exchange model showing knowledge flow from a single agency or entity (person, branch).

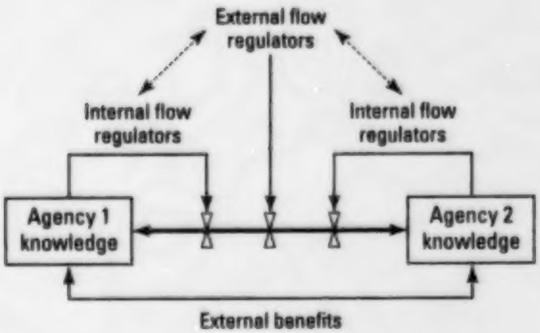

Figure 12. Knowledge exchange model showing knowledge flow between two agencies or entities (person, branch).

it available according to how it sets its organizational regulators. In this model, knowledge flows both into and out from the agencies.

In **Figure 13** the two-agency model is applied at a multi-agency or national level by adding another layer. Despite the apparent complexity of multiple boxes and arrows, there are no new concepts for the national model, simply the addition of national regulators. Note that at a national level, agencies can also exchange information bilaterally, independently of any larger group. Dotted arrows indicate that regulators influence but do not necessarily control information flow. Two-way arrows indicate that, in some cases, national regulators can be influenced by agencies. The model can be extended to an international level or to include as many layers as are needed for a particular application.

Although the model could incorporate additional layers, extension beyond three layers provides no new insights to the process. The model might also be applicable to individuals within the CFS. In this case, emphasis would shift from organizational culture and group dynamics to individual attitudes and behavior. The fundamental distinction between the interagency and intra-agency flow of knowledge is whether the arrows from the common regulators are dotted (interagency) or solid (intra-agency).

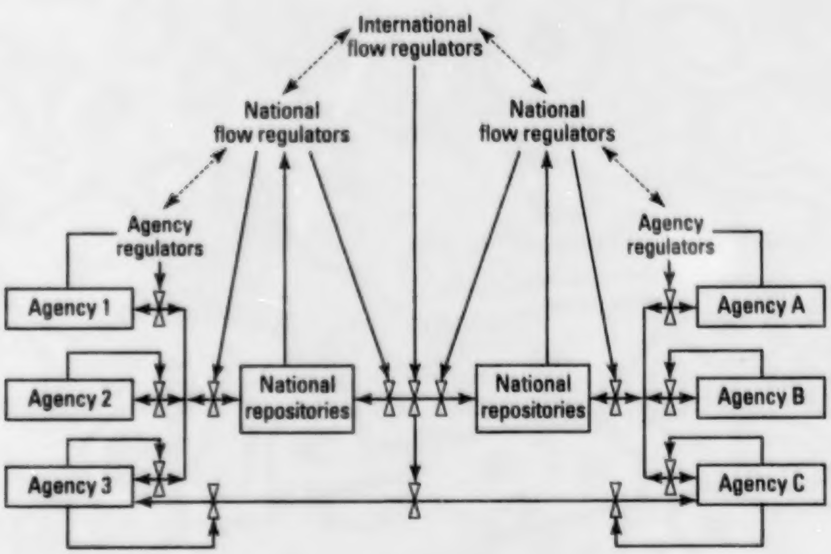

Figure 13. Knowledge exchange model showing knowledge flow at a multi-agency, national, or international level.

Flow regulators can either facilitate or inhibit the exchange of knowledge depending on how they are "set." Knowledge exchange can be regulated by environmental context, institutional restraints, domain attributes, technological capacity, and infrastructure.

Context regulators are external to organizations, common to all, and cannot be materially influenced. They affect the amount of knowledge providers make available. Context regulators can be categorized as follows:

- Issue-related (the problems that must be solved).
- Social (culture, beliefs, education, skills, language, communication).
- Economic (costs, values, pricing, property, liability).
- Domain-specific (process, function, hierarchical level).
- Benefit-related (return on investment, access to knowledge, leverage resources).

Institutional regulators are a societal construct and are thus generally amenable to modification at some level, albeit not easily or quickly. They affect the type, amount, use conditions, and format of the knowledge that providers make available. Institutional regulators can be grouped as follows:

- Organizational (authority, responsibility, policies, strategies, resources, expertise).
- National (governance, security, politics, power, laws, policies, trade, competitiveness).
- International (treaties, conventions, agreements, standards, protocols, guidelines).
- Benefit-related (visibility, humanitarian, foreign aid, partnerships, influence).

The domain attributes of the available knowledge must match those of the knowledge needed by outside agencies. For example, a general audience requires simplicity in presentation and language; for some groups, timeliness of the information is critical to monitoring; and for less developed regions, conventional technology is key to usability. Exchanging knowledge requires that the CFS and its clients share a common understanding of each other's capabilities and needs. Domain attributes describe the following:

- Content (scope, value, reliability, quality, format, timeliness).
- Provider (mandate, resources, culture, knowledge skills, technology).
- User (needs, resources, knowledge, skills, technology).

Without technology there can be no electronic exchange. Although the exchange is limited by the capability of the least-wired user, this capability is continually being expanded. The advantages of well-developed, commercially available technology and open standards are its general availability, reliability, and ease of maintenance. If the CFS becomes dependent on a particular level of technology, then that technology must be stable and robust enough to perform under difficult circumstances, whenever it is needed. Technologies that affect the flow of knowledge can be grouped as follows:

- Computer (mainframes, servers, PCs, notebooks).
- Communication (switching, transmission, distribution).
- Network (Internet, Intranet, World Wide Web, LAN).
- Satellite (capacity for monitoring, alerting, and incident support).
- Conventional (telephone, fax, radio).

An infrastructure provides a framework that enables the technology to support the exchange of knowledge among organizations. Several components of knowledge infrastructure must be considered:

- Directories (of people, expertise, organizations, services, content).
- Interoperability (for database compatibility).
- Metadata (to support information search and retrieval).
- Dissemination systems (to make knowledge available to clients, partners, and stakeholders).
- Acquisition systems (to find and retrieve knowledge from internal and external sources).

CFS K-If Framework

A framework for the CFS K-If will help to identify the components needed to develop the infrastructure. It will also support project management activities, such as identifying priorities, developing work schedules, assigning responsibilities, and allocating resources.

The CFS K-If framework presented here is based on the model of knowledge synthesis (Figure 10), the

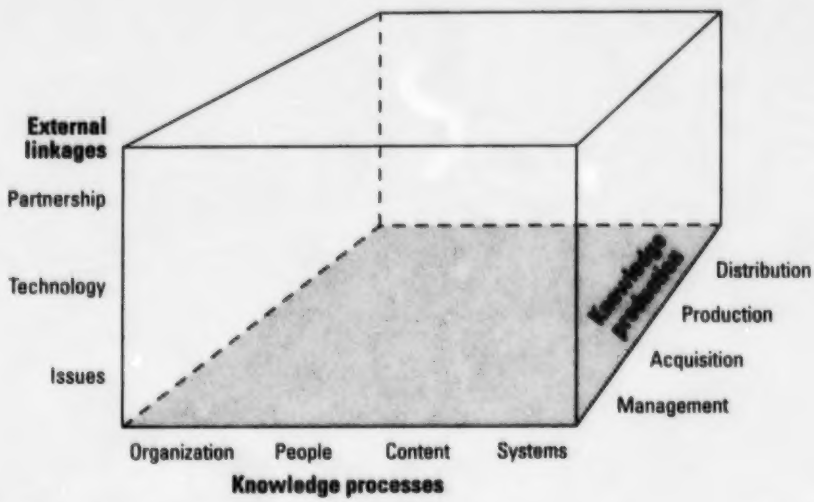

Figure 14. CFS Knowledge Infrastructure Framework.

CFS organizational structure, and the role of the CFS within Canada's forestry sector. It has three dimensions: knowledge production, knowledge processes, and external linkages (**Figure** 14). The dimensions relate to how the infrastructure can be integrated into the CFS organizational structure.

Knowledge Production

From an organizational perspective, knowledge production can be viewed as a sequential eight-stage process that acquires, produces, and disseminates knowledge:

- The search for existing knowledge (find out what is known about an issue).
- Data acquisition (acquire and extract data from internal and external sources).
- Database management (enter data, organize files, store and retrieve).
- Information management (translate data into information, produce reports).
- Knowledge synthesis (combine diverse information into a coherent whole, deduce, infer).
- Knowledge products (adapt knowledge to the needs of specific users).
- Dissemination (distribute knowledge products to partners, clients, and stakeholders).
- Application (use knowledge to address issues or solve problems).

The eight-stage process was successfully applied to two very different existing CFS knowledge activities: the Canadian Wildland Fire Information System (a fully automated quantitative modeling and mapping process) and the criteria and indicators of sustainable forest management (an evolving subjective process that identifies, monitors, and evaluates values that Canadians want to sustain). Therefore, the process should be applicable to most or all CFS knowledge activities.

To simplify the framework, the eight stages have been grouped into four categories, based on similarity of functions, expertise, and responsibilities.

- **Management** (overarching) gives organizational support, authorities, responsibilities, and resources. This involves providing strategic directions, allocating resource, establishing policies, and approving programs. The primary participants are managers and staff.
- **Acquisition** (stages 1 and 2) involves providing inputs to knowledge production through internal and external linkages. The focus is on search engines and taxonomies for organizing knowledge and the primary participants are information management and technology specialists.
- **Production** (stages 3–5) involves transforming data into knowledge through technology and systems that manage databases and information and synthesize knowledge. The primary participants are scientists, policy analysts, and systems analysts.

- **Dissemination** (stages 6–8) involves adapting, disseminating and using outputs from knowledge production. The primary recipients are external clients and partners. The primary participants are those with publishing, communication, and marketing skills.

Knowledge Processes

The second dimension of the knowledge infrastructure framework is the set of processes that combine to produce knowledge—the organization, people, content, and systems.

- **Organization** provides program structure and processes for management, a context for implementation, and a culture that must be modified to fully benefit from a K-If.
- **People** interact with systems to produce knowledge. Through the K-If, tacit knowledge that benefits the organization should be increased and better utilized to achieve organizational goals.
- **Content** can be expressed in terms of the complexity of electronically processing it, which can also be a surrogate for knowledge value. There are five levels of knowledge complexity—descriptive, static, updated, dynamic, and interactive.
- **Systems** support the production of knowledge; they are essential to working in a digital environment. There are four categories of systems—database management, information management, decision support, and expert systems.

External Linkages

The third dimension of the K-If framework involves external linkages to the environment that surrounds the CFS. External linkages have been divided into three groups—issues that drive the process, technology that supports it, and CFS partners, who own most of the forestry data in Canada.

- **Issues and mandate** drive the knowledge infrastructure. They provide reasons for its existence, direction for what it should do, and key applications for CFS knowledge products.
- **Technology** both enables and limits the knowledge infrastructure. The CFS K-If should focus on adapting well-developed commercially available information and communications technologies to support organizational goals. Rapid technological evolution mandates careful planning to minimize obsolescence.
- **Partners** produce and own most of the operational forestry data in Canada. The CFS K-If will involve negotiated data sharing with provincial agencies and industry associations.

CFS K-If Program Elements

This section outlines a set of program elements that will be needed to develop a CFS K-If. Each element is listed and briefly described under that part of the framework that best describes its primary purpose. Most proposed elements interact with other elements in the program matrix and the specific choice of where to put it is not critical to the overall structure.

Although only a few elements are absolutely essential, most of the 45 items in the following list are needed to develop a functional K-If for the CFS. Few elements could be deleted without significant loss of functionality. In all cases, however, the extent to which each element is developed is optional. Management decisions should focus on the degree of sophistication, amount of detail, relative completeness, and span of influence. As with the family car, a minimum number of components are needed to provide basic functionality but there are many kinds of cars and many options available for each.

Knowledge Production

Management

Knowledge inventory: An inventory of CFS knowledge assets and activities is an essential starting point for developing and managing a K-If. It would provide a comprehensive picture of current knowledge assets and activities as a basis for organizing them.

Digital policies: The CFS has few policies in place that apply to a digital environment. If traditional policies are applied directly, the CFS could become marginalized in a dynamic knowledge-based economy. The CFS should develop a set of policies that balance the needs of a government agency with the opportunities and challenges of a digital environment.

Digitization of holdings: The CFS has acquired and produced a considerable amount of forestry data, information, and knowledge. Because most is not

digitized, however, it is not available to support knowledge production or to be disseminated to clients in a digital environment. The CFS should identify its legacy knowledge holdings, evaluate their potential usefulness in a digital environment, and prioritize selected digitization projects.

Knowledge preservation: The CFS is in the business of producing knowledge. Preservation is the counterpart of knowledge production. It reduces the loss of knowledge resulting from continuous social, technological and organizational changes and evolution. The CFS should develop processes to preserve its most valuable assets—data, information, and knowledge.

Value of knowledge: Traditional accounting methods cannot measure intellectual capital. For example, they measure payroll cost but not the value of an employee's knowledge contribution to a product. Developing methods to determine the value of knowledge assets is a precursor to proper management.

Acquisition

Knowledge taxonomy: Although the classification of knowledge is as old as libraries, a digital environment provides new opportunities and poses new challenges to it. The CFS should adapt standard knowledge taxonomies and thesauri to organize its forestry data, information, and knowledge to allow easy and quick accessibility in a digital environment regardless of media or perspective.

Monitoring: Many CFS programs require periodic statistics on Canada's environment, forests, and forestry activity. Significantly more comprehensive data will also be required for measuring criteria and indicators of sustainable forest management. The CFS should develop an operational monitoring program in partnership with provincial agencies to record digital data to address increasingly complex issues of sustainable forest management.

Data acquisition: Acquisition systems communicate with remote data repositories, access databases, and transmit data to the requesting site. These systems also extract, validate, and correct data and archive data into databases. The CFS should expand its use of automated data-acquisition systems to provide input to national forestry databases.

Search and retrieval: Intelligent search engines are becoming essential for finding specific content in the rising flood of information that is published on the World Wide Web. For the CFS, this includes publication catalogues and library services. The CFS should select and adapt an existing generic search engine to enable users to find information within the CFS K-If.

Directories: There are many ways to search an organizational hierarchy—by programs, locations, products and services, people, expertise, and so on. The CFS K-If should incorporate a set of interconnected directories that are accessible with the search engine in order to facilitate finding any specific element of the organization.

Production

National databases: To fulfill its national forestry mandate, the CFS will require an expanded set of cross-domain national databases. Interoperability is the key to sharing data across CFS networks and programs. The CFS must adopt interoperability standards to enable cross-domain data sharing.

Information repositories: Although collectively the CFS holds considerable data, information, and knowledge, they are in many different formats and scattered across several sites. Metadata are essential to finding and retrieving knowledge. Metadata describe the attributes of a digital object independently of the object itself. The CFS must adopt metadata standards to enable knowledge sharing across the organization.

Knowledge synthesis: The synthesis of knowledge involves combining diverse concepts and multiple information sources into a coherent whole. The CFS K-If should incorporate analysis tools, systems, and processes that support and facilitate knowledge synthesis.

Dissemination

Digital products: Current publication and communication processes are generally based on traditional media. A digital environment provides multimedia and hyperlink opportunities as well as the challenge of dynamic, rapidly evolving technology. To maintain relevance in the knowledge economy, CFS knowledge products and processes must be adapted to a digital environment.

Intranet: The technology that enables global networking can also facilitate information sharing within an organization. In the CFS, networking is essential to the efficient functioning of widely dispersed teams.

The CFS K-If should incorporate an internal communication network to facilitate its operations.

Internet: The CFS Web site is a window between the CFS and the world. It focuses on disseminating digital knowledge, one of the primary objectives of a CFS K-If. The K-If must incorporate user interfaces that allow it to be easily and effectively accessible, both internally and externally, through the Web site.

Digital library: A digital library would comprise a multimedia collection of all CFS data, information, and knowledge, stored as digital objects in distributed repositories, and accessible through a national computer network. The CFS K-If should evolve towards a digital library as the ultimate method of providing access to CFS knowledge.

Knowledge Processes

Organization

Initiative management: A plan must be developed and approved, resources must be provided, work must be done, and accomplishments must be evaluated. Following good project management principles will be essential to the success of the CFS K-If.

Implementation: Implementation is necessary to the success of knowledge management. This involves several challenges, including bureaucratic dysfunctionality, checks and balances of the informal organization, and limited technological skills. The CFS K-If will have to be adapted to the organizational context.

Organizational change: The CFS K-If should have a capacity to support the development of shared organizational vision, goals, and values, and a culture that encourages the sharing of knowledge.

People

Learning: Knowledge workers need skills in information and computer technologies, an understanding of domain-specific subject matter, and real-world experience. The CFS K-If should incorporate processes that allow people to learn in knowledge management areas useful to the organization.

Knowledge capture: Tacit knowledge in people's heads is of limited value to the organization; it must be converted to explicit knowledge to be useful to more than one individual. The CFS K-If should incorporate technology, such as individual Web pages and a directory of expertise, to capture and codify individual knowledge.

Knowledge mobilization: The CFS needs to use more of what people know. The knowledge of many individuals must be combined to achieve strategic objectives. The CFS K-If should incorporate technology, such as list servers, discussion groups, shared data and information bases, and groupware, to support real-time remote interactivity among widely dispersed individuals.

Corporate memory: Knowledge is ephemeral, easily dissipated, and difficult to replace. Procedures are needed to archive and to share experiences and memories. The alternative is to duplicate work and repeat history. The CFS K-If should incorporate a capacity to preserve corporate memory.

Content

Descriptive sites: Web site "home pages" primarily describe an organization and its programs. When a Web site is first set up, the main objectives are usually to establish a presence for a group on the Web, promote the group, and acquire skills for staff in using Web technology. Most Web sites begin at this stage and continue carrying descriptive information as they evolve.

Static sites: Providing digital access to CFS information is the most visible and best-understood purpose for the K-If. The focus is on disseminating fixed information about a subject to people with a general interest in forestry. These sites usually include search capability and user feedback. Many CFS Web sites have evolved to this stage.

Updated sites: Some information systems are periodically updated and are useful for people who need current in-depth information. For example, users could download numeric data into their own spread sheets and perform custom calculations. Interactivity increases to include e-mail, discussion groups, statistical analyses, and report generation. This is the first stage of using Web technology for producing knowledge.

Dynamic sites: Some systems frequently or continuously update technical information for specialists who implement forest management activities. These systems usually require partnerships and interconnectivity among multiple distributed databases. Users can order products and services, manipulate data, and customize information.

Interactive sites: Some Web sites allow the user to create customized databases, analyze data, run models remotely, and synthesize new knowledge. These sites achieve the ultimate objective of supporting knowledge synthesis, policy development, and forest sector competitiveness.

Systems

Database management: Database management systems will need a capability to respond to queries, extract customized subsets of data, analyze the data, and produce reports. The CFS should select and adapt generic database management and data mining systems to enable users to produce new knowledge from existing data.

Information management: Information systems are central to transforming data into information. Technical systems use domain-specific processes that are often not adaptable outside the domain. Generic systems focus on managing information as a commodity and can be adapted to any type of information. The CFS K-If should incorporate both types of information systems.

Decision-support systems: Decision-support systems use domain-specific analyses and models to synthesize knowledge from multiple information sources. The CFS K-If should include a family of decision-support systems that apply scientific knowledge to support forestry decision-making.

Expert systems: Human reasoning and knowledge synthesis are as old as the human species. Recently, expert systems based on artificial-intelligence methods have made significant inroads into what has hitherto been considered more art than science. The CFS K-If should include expert systems to facilitate transforming tacit knowledge into explicit knowledge.

External Linkages

Issues and mandate

Sustainable forestry: Supporting sustainable forestry is a core element of the CFS mission. Measuring the criteria and indicators (C&I) of sustainable forest management requires integrated data, information, and knowledge from many CFS networks and programs. The CFS K-If should therefore focus on supporting C&I as an initial application.

Science–policy linkage: The CFS is the primary forestry research and policy coordinating agency in Canada. It is important that forest policies be based on sound scientific knowledge and that science priorities reflect key policy issues. The CFS K-If should incorporate methods to support policy analysis and development.

Forest sector competitiveness: Supporting forest sector competitiveness and market access is a core element of the CFS mission. This requires integrating socioeconomic data, market and trade information, and manufacturing technology. The CFS K-If should include methods to support forest sector competitiveness in a knowledge-based economy.

Technology

Computer: The information and communications technology revolution is built upon computer technology. The PCs on people's desks contain more raw processing power and storage capacity than early super computers, enabling very sophisticated information processing by individuals. Maintaining reasonably up-to-date PCs and systems will be essential to the CFS K-If.

Information: Information-processing software and systems are continuously evolving to take advantage of PC capabilities. The CFS K-If will require agency-wide, reasonably current office automation software and data and information management systems and technology.

Communication: Communication technology is the foundation for the Information Highway. It is key to connectivity across a widely dispersed organization. The CFS K-If will require periodic increases in bandwidth to accommodate ever-increasing amounts of information being moved from one place to another.

Network: Internet technology provides global and agency hyperlinked multimedia networking capability. Although only one of several channels for disseminating digital information, it is becoming increasingly important. The CFS K-If will require both Internet and Intranet capability for external and internal communications, respectively.

Partners

Global networks: The CFS participates in several initiatives related to global stewardship of forests, such

as sustainable development, global change, and global-scale science. The CFS K-If should support global initiatives by exchanging information and facilitating secretariat activities.

National networks: To accomplish its mission, the CFS requires data from forestry agencies and companies and they, in turn, benefit by access to national information and knowledge. The CFS K-If should facilitate development of a Canada-wide network for exchanging forestry data, information, and knowledge to ensure continuing success of the forest sector in the knowledge-based economy.

Extended networks: The CFS is a member of several extended networks related to science and technology and the forest industry. Information and communication technologies provide opportunities to enhance the activities of these networks. The CFS K-If should incorporate processes to support the activities of extended forestry networks.

Department: The relation between the CFS and its networks and programs mirrors that between the CFS and NRCan. The CFS K-If will have to interact with a larger departmental initiative. Mutually agreed sector and corporate roles and responsibilities should be established to eliminate duplication and enhance efficient resource utilization.

Domain: Most CFS content is created by the CFS S&T networks and programs, usually through domain-specific partnerships with external counterparts. Such partnerships are essential to the ultimate achievement of CFS goals and objectives. Web technology is currently supporting linkages with domain-specific partners; the CFS K-If could significantly strengthen their interactivity.

Part 3 A Knowledge Initiative

> *The smooth and effective transformation towards the information society is one of the most important tasks that should be undertaken in the last decade of the 20th century.*
>
> —G7 Information Society (1995, "Vision Statement")

In Part 2, the technical architecture for managing CFS knowledge was presented. Part 3 focuses on the social architecture of institutional processes by considering how the CFS might build and implement its knowledge infrastructure. An overview is given of the CFS knowledge initiative (K-It) in terms of organizational processes and the role of the K-It in relation to all CFS knowledge activities. An outline of a proposed strategic plan follows; it summarizes objectives and benefits, guiding principles, the scope of the initiative, priority setting, and next steps.

Overview

Wise men weigh the advantages of any course of action against its drawbacks, and move not an inch until they can see what the result of their action will be; but while they are deep in thought, the men with self-confidence "come and see and conquer."

—Asher Ginzberg (1856–1927)

Knowledge Initiative Framework

When the laws of knowledge management are eventually proven, one of the first will no doubt be that knowledge management is a social construct that cannot exist in and of itself; it must exist within a social (organizational) context. Therefore, the purpose of the CFS K-It is to develop a knowledge infrastructure within the context of the CFS. The K-It can be summarized graphically (see **Figure 15**) or with a series of equations (with license for mathematical imprecision) as follows:

(1) Knowledge initiative = capacity building × organizational context.

In essence, the CFS K-It combines what the CFS *can* do with what it *chooses* to do. Put another way, it combines an engineering function (build the box) and an organizational function (use it). Here, as in the other equations, the multiplication sign indicates that if either part is missing, nothing happens, or alternatively, that the total output is limited by the smallest element.

(2) Capacity building = resources × $_{min}$ (infrastructure, content).

(3) Organizational context = leadership × culture × learning.

Developing capacity requires something to build with, the structure to be built, and something to put in it. The total output is determined by the lesser of the latter two. An infrastructure without content is a hollow shell; content without infrastructure is the present state of affairs. Organizational context comprises three elements: a decision that we are going to do something (leadership), agreement by all concerned to do it together (culture), and people who know how to do it (learning).

(4) Resources = funds + people + time.

(5) Infrastructure = technology × systems + management.

(6) Content = acquisition + production + dissemination.

Equations 4–6 expand the three elements of equation 2, capacity building. These elements were previously discussed in Part 2.

(7) Leadership = vision × direction × commitment.

(8) Culture = change × (sharing/controlling).

(9) Learning = education + skills + experience.

Equations 7–9 expand the three elements of equation 3, organization context. These elements were previously discussed in Part 1.

Role of the Knowledge Initiative

It is useful to consider the role of the knowledge initiative in relation to existing CFS knowledge activities. CFS knowledge activities can be visualized as three concentric layers (**Figure 16**).

Figure 15. CFS Knowledge Initiative framework.

Figure 16. Knowledge management activities at the CFS.

The National Forest Information System (NFIS) can be thought of as the core of CFS knowledge activities. This is the operational system that is intended to acquire, integrate, process, and disseminate data and information from autonomous, distributed databases to support analysis of and reporting on diverse forestry issues. The NFIS will provide data and information to knowledge synthesis activities in the middle ring. The middle ring, will, in turn provide new knowledge and scientific models to the NFIS.

The middle ring aggregates existing knowledge activities within the CFS S&T networks and national forestry programs. In Figure 16, they are collectively referred to as "knowledge management." In the CFS's Target Outcome Task Group Report (unpublished internal document, 1999), this layer is called "Target Outcome 1a—Synthesis and Integration of Knowledge and Provision of Systems for Enhanced Decision-Making Capability." Here knowledge is created through science and content is produced by programs. The

middle ring acts as an intermediary between the operational central core and the outer planning shell. It supplies knowledge to the NFIS core, provides a program framework for knowledge activities, and implements policies and strategic plans developed in the outer knowledge initiative shell.

The outer shell provides an overall umbrella for CFS knowledge activities. This is the realm of the CFS K-It. Activities include policy formulation, strategic planning, and initiation of new activities and programs. Once established, policies, plans, and activities move to the to the middle layer for implementation.

Developing a Strategic Plan

Our plans miscarry because they have no aim. When a man does not know what harbor he is making for, no wind is the right wind.

—Seneca (4 BC–AD 65) (Quoted in Forbes 1997, Thoughts on Wisdom)

Developing a strategic plan begins with creating a vision and purpose—where we are going and why. Although there is more than enough material for these tasks in the preceding pages, anything written by this author will be just that, one person's views. These tasks are best accomplished through the thrust and parry of debate, so that the outcome is a consensus based on a diversity of opinions.

This section begins by proposing a set of objectives, benefits, and guiding principles for the CFS K-It. This is followed by proposed processes for defining the scope of the initiative and for prioritizing the list of potential program elements. Finally, a path for transforming the concepts presented in the K-It framework into a strategic plan is suggested.

Objectives, Benefits, and Principles

The CFS K-It has six objectives:

- Manage CFS knowledge assets.
- Link knowledge and foster sharing across CFS networks and programs.
- Enhance knowledge synthesis and production of knowledge products in the CFS.
- Disseminate digital data, information, and knowledge about Canada's forests.
- Facilitate knowledge production to support sustainable forest management in Canada.
- Share knowledge to promote the competitiveness of Canada's forest sector.

The first three objectives relate to organizational efficiency and effectiveness. They are a prerequisite to the next three objectives, which relate to the CFS mandate as the federal forestry agency in Canada.

A CFS knowledge initiative will yield a broad set of benefits, both institutionally and for Canada's forestry clients, partners, and stakeholders:

- Processes and systems for managing CFS knowledge assets.
- Better linkages among CFS's islands of knowledge.
- Reduced duplication of effort and individual self-learning.
- Improved access to internal and external digital information holdings.
- Creation of new knowledge beyond what is currently possible.
- Increased efficiency and effectiveness of knowledge synthesis.
- Increased dissemination and application of CFS knowledge products.
- Support of the NRCan knowledge initiative by contributing forestry content.
- Facilitation of the evaluation of criteria and indicators of sustainable forest management.
- Positioning of the CFS in the forefront of the emerging knowledge-based economy.
- Promotion of forest sector competitiveness in the knowledge-based economy.
- Enhancement of CFS's contribution and value to Canada's forestry community.
- Increased visibility of the CFS, its programs, and activities.

Strategic principles should give overall direction to the CFS K-It:

- Science is an inherent strength of the CFS.
- Well-developed technologies should be used where appropriate.

- Development should be through consensus, not direction.
- Compatibility should be fostered but different perspectives should be permitted.
- Networks and programs should maintain responsibility for content.

Principles of knowledge processes should guide the design of the CFS K-It:

- Technology should be a means to an end, not an end in itself.
- Technology should exist within an organizational, social, and cultural context.
- Presentation and content should be equally important.
- Information should be available as needed, not as information overload.
- Benefits of sharing information should exceed the burden of doing so.

Management principles should direct the development of the CFS K-It:

- The K-It should expand from project-scale successes.
- There should be short-, medium-, and long-term objectives and deliverables.
- There is a minimum functionality, below which the K-It will have little utility.
- Implementation strategies should be integral to all development activities.
- The needs of clients and partners should be incorporated into the K-It.
- Resources should be leveraged to maximize cost-effectiveness.

Principles of sharing knowledge should guide the implementation of the CFS K-It:

- Knowledge should be shared.
- Knowledge should be accessible.
- Knowledge should be user-focused.
- Knowledge should enable more effective work.
- Knowledge is a valuable resource.
- Knowledge management is everyone's responsibility.

Scope of the Knowledge Initiative

Every CFS program could be categorized according to how it relates to the K-It; conversely, the K-It could be related to every program. Although conceptually defensible, relating everything to everything is not particularly useful from the perspective of program structure, mandates, roles, budgets, and responsibilities. The K-It is but one of many CFS programs. We must, therefore, render traditional activities unto traditional programs and render unto the K-It only those activities that belong there.

Defining a boundary between the K-It and traditional programs is not straightforward. This is complicated by the strong interconnectivity between the two. One way around an elusive definition is to compare the attributes of activities on each side of the boundary (**Table 9**).

Some K-It attributes seem to be more important than others—objectives and deliverables, digital media, knowledge as an asset, knowledge management, knowledge application, and cross-domain integration. The attributes in Table 9 do not provide a well-defined boundary between the traditional and K-It worlds because many CFS activities have characteristics of both. Classification should be based on the proportion of criteria that could be assigned to one or the other side of the boundary. Collectively these criteria should help to classify activities as more appropriate to K-It or traditional programs.

Next Steps

The CFS K-It has existed mostly in people's minds and on paper. It must be converted from concepts and ideas to the reality of programs and deliverables with associated resources and responsibilities. The following steps are proposed as a process for developing a strategic plan for the CFS K-It. Note that the first three steps have been completed.

1. **Develop consensus:** Obtaining a consensus that the proposed framework is appropriate for the K-It is the first step.
2. **Select a champion:** Continued support from senior management is essential. This will be greatly facilitated if a member of the CFS Management Committee sponsors the K-It.
3. **Obtain approval for the framework:** Formal endorsement of the framework is an essential step in establishing the K-It.

Table 9. Attributes of knowledge initiative activities and comparable attributes of traditional programs.

Knowledge initiative	Traditional program
Knowledge objectives and deliverables	Program objectives and deliverables
Knowledge synthesis support	Knowledge synthesis
Digital media and products	Traditional media and products
Digital library searches	Literature searches
Digital objects exchanged	Traditional media exchanged
Information systems developed	Process models developed
Information systems used	Traditional information processes used
Knowledge viewed as an asset	Knowledge viewed in terms of meaning
Data acquired	Experiments, surveys conducted
Database management	Data analysis
Information management	Records management
Knowledge management	Management of mail, files, meetings
Science outputs used	Science methods used
Knowledge application	Knowledge creation
Digital publication media	Traditional publication media
Knowledge dissemination	Technology transfer
Cross-domain content	Domain-specific content
Cross-process activities	Process-specific activities
Vertically integrated knowledge	Stage-specific knowledge
Horizontally integrated knowledge	Domain-specific knowledge

4. **Inform the CFS:** The K-It is a complex undertaking that will affect most CFS staff and programs. Developing readily understandable messages about the K-It will be challenging. Communication should begin as soon as possible.

5. **Select issues:** To focus development of the CFS K-It, no more than three issues should be addressed initially. Selecting one issue will increase the probability of success and reduce development effort; however, selecting two or more issues will increase the robustness of the K-If.

6. **Prioritize elements:** The full set of suggested K-It elements included in the framework need to be listed in order of priority so that a manageable set can be selected for initial development (see Appendix 3).

7. **Survey activities:** By determining what K-It activities are currently under way in the CFS, existing work can be leveraged, duplication avoided, gaps disclosed, and responsibilities suggested.

8. **Survey best practices:** Existing best practices should be surveyed for applicability to the K-It. This will help to identify those components of the K-It that should be developed and the effort that will be required.

9. **Develop scenarios:** A set of strategic scenarios related to various resource levels should be developed. These can be used to guide the scale and scope of the initial K-It.

10. **Establish funding level:** Approval in principle should be obtained from the CFS Management Committee for a resource level for the K-It. This will provide a context for developing a strategic plan.

11. **Prepare a strategic plan:** A five-year strategic plan for the K-It should be drafted and circulated for review and comment within and outside the CFS.

12. **Obtain approval for strategic plan:** The draft strategic plan should be submitted to the CFS Management Committee for review. It should be revised as necessary and resubmitted for approval.

13. **Develop an action plan:** A three-year action plan comprising specific projects, responsibilities, resources, milestones, and deliverables will be needed to begin implementing the strategic plan.

14. **Develop a communication plan:** A communication plan will be needed to outline how CFS staff and its clients, partners, and stakeholders will be informed about the K-It and its accomplishments.

The strategic plan should discuss the following:

- Social, economic, and forestry context for the CFS K-It.
- Opportunities and challenges of action and inaction.
- Consultations with clients, partners, and stakeholders.
- Roles of the CFS, clients, partners, and stakeholders.
- Benefits to the CFS and its clients, partners, and stakeholders.
- Statements of vision and purpose.
- Overall goals and objectives.
- Guiding principles for developing and implementing the K-It.
- Strategic direction and priorities.
- K-It programs.
- Milestones and deliverables.
- Internal and external linkages and leveraging.
- Reporting and review.
- Evaluating efficiency and effectiveness.
- K-It management structure.
- Financial and human resources.
- Technology and system resources.
- Knowledge and skill resources.

Summary

> *Until one is committed, there is hesitancy, the chance to draw back, always ineffectiveness. The moment one definitely commits oneself, then providence moves too. All sorts of things occur to help one that would never otherwise have occurred. Boldness has genius, power, and magic in it. Begin it now.*
>
> *—Johann Goethe (1749–1832)*

A revolution in information and computer technologies (ICT) is changing the way we live, how we work and do business, how we educate our children, study and do research, train ourselves, and how we are entertained. The changes are expected to reshape the world on a scale equal to the agricultural and industrial revolutions. Sweeping predictions include the death of distance and the disappearance of borders as significant factors, the demise of bureaucracies and economies of scale as industrial truisms, and wholesale realignment of economies from material to intellectual values. Organizations that do not make the transition to the knowledge society are predicted to become irrelevant or cease to exist.

A range of actions with respect to knowledge management is available to the Canadian Forest Service (CFS), Natural Resources Canada. The CFS could continue to use traditional knowledge management practices, although this might lead to its marginalization, or it could adapt traditional processes sufficiently to allow it to function in the evolving knowledge economy. However, the CFS could also implement deep and broad technical and organizational changes in order to realize full participation in a knowledge-based society. With a strategic investment in a knowledge infrastructure, the CFS could position itself as a leader in the 21st century.

The use of the World-Wide Web to disseminate knowledge is well recognized and understood. This is the primary use envisaged by most proponents and mandated by the federal government. The CFS is a science organization. If the CFS is to position itself as a leader in a knowledge-based society, it will likely be through using ICT to create and disseminate science-based forestry knowledge.

Forestry knowledge has properties that affect how it should be managed. It has spatial and temporal scales that range from molecules to the entire planet and from seconds to centuries. It encompasses a variety of assets—data, information, and knowledge—and can be viewed from a multitude of perspectives—provider or user, science or policy. To be effective and efficient, the CFS knowledge management architecture and processes will have to relate to the many properties of forestry knowledge.

Three objectives of knowledge management at the CFS relate to internal efficiency and effectiveness: to enhance the creation of new knowledge, to improve the management of knowledge assets, and to foster the sharing of knowledge. Accomplishing these will allow the CFS to disseminate information about Canada's forests, support the sustainable development of Canada's forests, and promote the competitiveness of Canada's forest industry.

Organizations that plan the transition to the knowledge society will be further ahead than those that just let it happen. The knowledge infrastructure framework presented in this publication is the CFS's first step in the planning process. The framework describes the knowledge infrastructure, why the CFS should develop one, and what an infrastructure would do. It identifies the necessary components of an infrastructure, how they relate to each other, and how to prioritize them. The framework functions as a map to help the CFS decide where it wants to go and how to get there.

The knowledge infrastructure has three dimensions. The first is knowledge production: finding and acquiring data, transforming data into information, creating knowledge, and distributing knowledge products. The second dimension is organizational processes, people using systems to produce knowledge within a context of organizational programs, processes, and culture. The third dimension links the infrastructure to the outside world through issues, technology, and partners.

Producing knowledge integrates six processes:

- Issues provide a purpose
- Government provides an institutional context.

- People undertake activities, such as analyzing, deciding, and reporting.
- Information is processed through several stages: data, information, and knowledge.
- Systems manage databases and information and support decisions.
- Technology supports information systems.

Exchanging knowledge is based on a simple premise—the amount exchanged is proportional to that produced and that which is made available. Several factors affect the exchange of knowledge:

- Context, including natural and social processes that cannot be materially changed.
- Institutional constructs, such as policies, that can be changed to some extent.
- Attributes of the content, user needs, and provider mandates.
- Technology to communicate and process knowledge.
- Infrastructure to disseminate and acquire knowledge.

The knowledge initiative comprises two interwoven yet distinct halves—developing the technological capacity to produce, manage, and disseminate knowledge (the infrastructure) and instituting organizational processes to implement it. Neither is sufficient without the other; both are necessary to success. In relation to CFS programs, the knowledge initiative can be viewed as a "virtual" outer shell that provides a context for existing knowledge management activities, which, in turn, provide inputs to and receive outputs from a core National Forest Information System.

Implementing the knowledge initiative will involve some basic changes in how the CFS does business. This will require, first and foremost, a shared vision and commitment on how the CFS will move towards the future. Computers, communications, networks, and knowledge management will become central to how people work. Policies and processes will have to be adapted to a digital environment. Bureaucracy will have to be able to respond to a changing, fast-paced world. Information will have to be readily shared across all networks and programs. The CFS will have to be able to thrive in a world where the only constant may be rapid change. Lifelong learning will be mandated in a society in which the rate of obsolescence of education and skills will continue accelerating.

This publication concludes with a recommended process to transform the framework into a strategic plan to implement a CFS knowledge initiative. It includes proposed objectives, benefits, and principles. Criteria are provided for categorizing existing knowledge activities within the knowledge initiative or traditional science and technology programs. Finally, a process is recommended for prioritizing the full set of potential program elements into a manageable group to begin the process.

Appendix 1 Laws and Policies Affecting a CFS Knowledge Initiative

Laws

> *The wrong policy decisions could easily destroy this glittering promise and make the Electronic Highway Networks no more than computer/communication equivalents of today's commercial TV networks or, more ominously, dangerous instruments of repression.*
>
> —Douglas Parkhill, *Gutenberg Two* (1982)

The Federal Task Force on Digitization (1997) identified 25 acts relating to federal information. The following 11 have implications for and application to the development and implementation of a CFS K-It.

Access to Information Act provides Canadians with a right of access to traditional and digital records held or controlled by government in accordance with the principle that government information should be available to the public and that necessary exceptions should be limited and specific. The World Wide Web could provide an opportunity to make documents more readily accessible to the public.

Canadian Charter of Rights and Freedoms, part of the *Constitution Act*, outlines the rights and freedoms of Canadians. One section provides for the equality of the status of English and French as Canada's official languages, and equal rights and privileges as to their use in all the institutions of the Parliament and Government of Canada. The ***Official Languages Act*** provides the legal framework to ensure respect for the equality of English and French. The legal requirement for bilingual government sites will require adequate resources for rapid translation in an HTML or other appropriate digital format. Inadequate translation resources will be a barrier for government sites in the dynamic environment of the World-Wide Web.

Copyright Act sets out rights that attach to literary, artistic, dramatic, and musical works, sound recordings, performances, and broadcast signals. It also specifies some exceptions to these rights. In principle, copyright laws applicable to digital works are no different from those applicable to works in more familiar formats. To be protected by copyright, a digital work must be original, must be expressed in some material form (capable of identification and having a more or less permanent endurance), and must meet certain conditions concerning the nationality of the author and place of publication. Examples of protected digital works are an electronic book or a digital recording. Online material is protected if it is fixed in some form, for example, as a print-out, or if it is saved on a floppy disk or hard drive. Some interactive works may meet the condition of fixation, but problems of protection may arise for creators of such digital works under the current *Copyright Act*.

Department of Natural Resources Act charges the Minister of Natural Resources to have regard for the sustainable development of Canada's natural resources; participate in the development and application of codes and standards for natural resource products; enhance the competitiveness of Canada's natural resource products; participate in the enhancement and promotion of market access for Canada's natural resource products; and coordinate and disseminate information respecting scientific and technological developments affecting Canada's natural resources. This provides a clear mandate and direction for the CFS K-It.

Department of Public Work and Government Services Act controls procurement activities, including communications. It prescribes the Queen's Printer as the sole government publisher, although some administration of publishing activities may be delegated to departments. Currently only printed documents are considered officially published; formal dissemination through Internet occurs only after a printed document is released.

National Archives of Canada Act establishes the National Archives of Canada to conserve and facilitate access to private and public records of national significance. It is the permanent repository of government and ministerial records, it facilitates government records management, and it encourages archival activities. The National Archives of Canada also preserves digital information and ensures continuing access by conversion to new media as needed. Some historical CFS digital databases are accessible today only because they were filed with the National Archives more than two decades ago.

National Library of Canada Act empowers the National Librarian to manage the National Library of Canada to provide access to its holdings to the government and people of Canada. It preserves Canada's published heritage through the legal deposit of publications.

Privacy Act protects the privacy of individuals with respect to information on them held by government institutions and provides those individuals with a right of access to that information. This determines what can and cannot be made available through publicly accessible directory searches of personnel and expertise.

Statistics Act requires Statistics Canada to collect, compile, analyze, abstract, and publish statistical information relating to commercial, industrial, financial, social, economic, and general activities and condition of Canadians and the activities of other federal departments. Some data and information needed to fulfill the CFS mandate are obtained from Statistics Canada; the CFS submits information on forestry activities to Statistics Canada.

Telecommunications Act mandates Industry Canada to facilitate development of a telecommunication system to safeguard, enrich, and strengthen the social fabric of Canada; provide affordable, reliable, high quality, and accessible telecommunications services; enhance the efficiency and competitiveness of Canadian telecommunications; promote Canadian use, ownership and control of Canadian facilities; foster reliance on market forces for providing telecommunication services; ensure efficient and effective regulation; and stimulate research and development in telecommunications. Whatever form the CFS K-If adopts, it will be dependent on the Canadian telecommunications infrastructure.

Note: Particulars of these acts can be found on the Department of Justice Canada Web site "Laws of Canada" <http://canada.justice.gc.ca/Loireg/index_en.html>.

Policies

The following federal policies and guidelines will affect development of a CFS K-If.

Alternative Formats: Access for All guides departments and agencies on the communication needs of people with visual and hearing disabilities and how to meet these needs.

Common Services Policy outlines mandatory and optional communication and publishing services.

Contracting Policy provides the framework for contracting for communications services, notably those related to advertising and public opinion research.

Cost Recovery and Charging sets guidelines for cost recovery and charging activities of departments and agencies. It emphasizes the need for participatory consultation among departments, agencies, and their clients.

Depository Services Program provides Canadian federal documents in hard and virtual formats to a network of libraries across Canada and around the world. Depository institutions catalogue, house, and make these documents accessible; maintain holdings; and provide expertise and tools for effectively using federal documents.

Federal Identity Program enables the public to clearly recognize federal activities by means of consistent identification, improves service to the public by facilitating access to federal programs and services, projects equality of status of the two official languages, ensures effective management of the federal identity, and achieves savings through standardization. This clearly affects the design of Web pages.

Government Communications Policy outlines three principles underlying the federal government's responsibility to disseminate information to Canadians. It promotes three core propositions of what government will do, and it contains guidelines regarding information for which the government will not charge.

Information Technology Security Standard ensures the confidentiality of information stored, processed, or transmitted electronically; the integrity of the information and related processes; and the availability of information, systems, and services.

Management of Information Technology ensures that information technology is used as a strategic tool to support government priorities and program delivery, to increase productivity, and to enhance service to the public.

Policy on the Management of Government Information Holdings ensures cost-effective and coordinated management of federal documents and records.

Preservation of Essential Records discusses essential records and provides guidelines on establishing an essential records program within the context of emergency preparedness and business resumption planning.

Science and Technology Policy establishes four goals for science and technology in Canada: sustainable job creation, economic growth, improved quality of life, and advancement of knowledge. It prioritizes funding to focus on core activities, creates institutions and mechanisms for the governance of Canada's S&T infrastructure, and provides strategic direction for federal S&T.

Note: Many of the above policies are issued by the Treasury Board of Canada Secretariat and can be accessed through its Web site, "Publications and Policies" <http://publiservice.tbs-sct.gc.ca/pubpol_e.html>.

Appendix 2 CFS Knowledge Management Activities

> *Whether we know it or not, most of us are already engaged in either resisting — or creating — the new civilization.*
>
> —Alvin Toffler, *The Third Wave* (1980)

Considerable activity relating directly to managing knowledge is currently under way at the CFS. Collectively, these activities provide the content without which the K-If would be a hollow shell. Many activities relate to transforming data into information and knowledge synthesis. They tend to go beyond simply disseminating information, which is the focus of most initiatives. This suggests a natural evolution towards a science niche where CFS strengths and experience could be used to add value to information in a knowledge-based economy.

An informal survey in 1998 disclosed 78 knowledge management activities across the CFS. The associated Web sites can be classified as descriptive (30), static (10), updated (14), dynamic (3), interactive (3), under development (10), digital applications (non-network) (3), and Intranet (5). Knowledge activities have only just begun; the challenge for the CFS K-It will be to integrate it into a coherent whole. Although the survey was out of date as soon as it was completed, it provides a snapshot of the range and depth of knowledge management activities in the CFS.

Program and elements	CFS knowledge management activities
Management	
Assets inventory	Year 2000, NRCan information holdings, NRCan databases, Internet sites.
Policies	Traditional policies are directly applied to a digital environment without modification.
Digitization	Most current information processing is digital; little effort is under way to digitize legacy holdings.
Preservation	Preservation is entirely dependent on individual initiative.
Valuation	None.
Acquisition	
Taxonomy	Information is organized by S&T networks and programs.
Monitoring	Acid Rain National Early Warning System, ASEAN Fire Weather Information System, Canadian Wildland Fire Information System, Canadian Council of Forest Ministers (CCFM) Criteria and Indicators, Montreal Process Criteria and Indicators, Mesoscale Weather Modeling, National Forest Health Information System, National Forest Inventory, National Forestry Database, National Survey on the Importance of Nature, North American Maple Project.
Data acquisition	Acid Rain Early Warning System, ASEAN Fire Weather Information System, Canadian Wildland Fire Information System, Mesoscale Weather Modeling, National Forestry Database.
Search/retrieval	CFS HQ, some forestry centers, CFS publications.
Directories	CFS HQ, forestry centers, directory of clients, directory of expertise.
Production	
National databases	Acid Rain National Early Warning System, Forest Health Information System, Forest Insect and Disease Survey, Forest Pathology Database, National Database on Federal Lands, National Database on Forest-Reliant Communities, National Forestry Database, national forest fire databases, National Forest Inventory, remote-sensing image databases. There are no interoperability standards for exchanging data.
Information repositories	Amphibians and Reptiles of Ontario, Biosystematics, Herbarium On Line, Licensable Technology, National Genetics Experiments Database, National Tree Seed Center, *Publications Digest*. There are no metadata standards for exchanging information.
Knowledge synthesis	CFS Knowledge Initiative.

(Continued)

Program and elements	CFS knowledge management activities
DISSEMINATION	
Products	Forest Disease Knowledge Base, Forest Insect and Disease Knowledge Base, *Trees in Canada*, Tree Tales, TREEVIA.
Intranet	Common Office Environment, Government Financial System, Human Resource Information System, Network Management Information System, Spatial Data Infrastructure.
Internet	CFS HQ, all forestry centers, all S&T networks, most programs, many project-level activities.
Library	Digital information cataloging and searches.
ORGANIZATION	
Initiative	Participation in ResSources (NRCan), development of a CFS K-It framework.
Implementation	Thousands of Web pages are available; many S&T Networks and programs are developing domain-specific sites; there has been little coordination to date.
Organizational change	The need for change has been identified.
PEOPLE	
Learning	Self-learning, training programs.
Knowledge capture	Directory of expertise, Traditional Ecological Knowledge of First Nations.
Knowledge mobilization	E-mail, Common Office Environment.
Corporate memory	None.
CONTENT	
Descriptive sites	CFS HQ, all forestry centers, all S&T networks, most programs, many project-level activities.
Static sites	Amphibians and Reptiles of Ontario, CCFM Criteria and Indicators, Montreal Process Criteria and Indicators, National Forest Strategy, Pacific Yew and Taxol, *The State of Canada's Forests*, Tree Care.
Updated sites	Acid Rain National Early Warning System, Forest Health Information System, Forest Insect and Disease Survey, National Forestry Database, National Forest Inventory.
Dynamic sites	ASEAN Fire Weather Information System, Canadian Wildland Fire Information System, Mesoscale Weather Modeling, National Fire Situation Reports.
Interactive sites	National Georeferenced Resource Information for Decision-makers.
SYSTEMS	
Database management	All databases use some form of database management system; there are no standards for selecting and implementing systems.
Information management	All management functions and libraries use information management systems; no systems are in place to manage unpublished information assets.
Decision-support	Forest health, landscape management, ecosystem management, fire management, remote sensing.
Expert	Tree Diseases Knowledge Base, Vegetation Management Advisory System.
ISSUES	
Sustainable forestry	CCFM Criteria and Indicators, Montreal Process Criteria and Indicators, National Forest Strategy.
Science–policy linkages	Integrating science and policy workshops.
Competitiveness	None.
TECHNOLOGY	
Computers	Common Office Environment–80% 166+Mhz Pentium PCs installed and maintained.
Information	Common Office Environment–word processor, spread sheet, graphics, database software installed (1997) and supported, GIS capability at most locations.
Communication	Common Office Environment–1.5 Mbps to 56 kbps connectivity at various locations; 100Mbps broadband data line (Pacific Forestry Centre).
Networks	Common Office Environment–e-mail, scheduler, Internet browser, Intranet installed and supported.

(Continued)

(Continued)

Program and elements	CFS knowledge management activities
Partners	
Global networks	Climate change, international conventions, Montreal Process Criteria and Indicators.
National networks	CCFM–Canada's Forest Network, Canadian Forest Sector S&T Network.
Extended networks	National Biodiversity Information Initiative, First Nation Forestry Program, Model Forests.
Department	CFS K-If and ResSources, NATGRID and Canadian Geospatial Data Infrastructure, National Forestry Database and Soft Access, Forestry databases and National Atlas.
Domain	Most S&T networks and programs have established domain-specific partnerships.

Appendix 3 Setting Priorities for Implementing a CFS Knowledge Intiative

> *Two roads diverged in a wood and I—*
> *I took the one less traveled by*
> *and that has made all the difference.*
>
> —Robert Frost (1874–1963), *The Road Not Taken*

Success in implementing knowledge management depends on focusing initial efforts on limited, achievable goals. Thus key elements that can be used to phase-in an overall initiative need to be identified.

To evaluate the relative importance of various program elements, a prioritization process is proposed in which the intuitive views and opinions of a group of interested and informed people will be elicited, codified, aggregated, and ranked. Each of the 45 program element would be subjectively rated as high, medium, or low with respect to five attributes:

- Importance—How important is the element to knowledge management?
- Impact—To what extent will the element affect the forestry community?
- Gap—How large is the gap between what is being done and what is needed?
- Time—How long will it take to develop and implement the element?
- Resources—How much will it cost and how many people will be needed?

Note that for importance, impact, and gap, a high rating increases the priority, while for time and resources, a high rating decreases the priority. Point scores can be attached to each attribute (positive: high (3), medium (2), low (1); negative: high (–3), medium (–2), low (–1). The five attribute scores for each element are added to determine an overall priority rank. Doing this for every element yields a distribution of priority ranks for all elements. A test of the process yielded an excellent range from highest to lowest priorities that could be used to divide the overall initiative into a variety of manageable parts. It also disclosed, however, that prioritization should be done by a cross-section of reasonably well-informed raters to avoid biased results.

Other factors, not considered here, will affect the final choice of initial elements, such as elements that must be completed before others can begin, elements that must be coordinated with the NRCan knowledge initiative, and elements that offer short-term deliverables.

Three matrices that can be used in setting priorities within the framework for the infrastructure follow.

CFS Knowledge Initiative–Priority Matrix
1. Knowledge Production

	Importance (+)	Impact (+)	Gap (+)	Time (-)	Resources (-)	Total	Priority
Management							
Knowledge inventory							
Digital policies							
Digitization of holdings							
Knowledge preservation							
Value of knowledge							
Acquisition							
Knowledge taxonomy							
Monitoring							
Data acquisition							
Search and retrieval							
Directories							
Production							
National databases							
Information repositories							
Knowledge synthesis							
Dissemination							
Digital products							
Intranet site							
Internet site							
Digital library							

CFS Knowledge Initiative–Priority Matrix

2. Processes

	Importance (+)	Impact (+)	Gap (+)	Time (-)	Resources (-)	Total	Priority
Organization							
Initiative management							
Implementation							
Organizational change							
People							
Learning							
Knowledge capture							
Knowledge mobilization							
Corporate memory							
Content							
Descriptive sites							
Static sites							
Updated sites							
Dynamic sites							
Interactive sites							
Systems							
Database management							
Information management							
Decision-support							
Expert							

CFS Knowledge Initiative–Priority Matrix
3. External Links

	Importance (+)	Impact (+)	Gap (+)	Time (-)	Resources (-)	Total	Priority
Issues and mandate							
Sustainable forestry							
Science–policy linkage							
Forest sector competitiveness							
Technology							
Computer							
Information							
Communication							
Network							
Partners							
Global networks							
National networks							
Extended networks							
Department							
Domain							

Terminology

> *Information is both elusive and illusive; it is difficult to define and deceptively easy to underestimate.*
>
> —Robert Galliers (1987, "Preface")

Emerging disciplines have always struggled with describing themselves. Social periods use *post* this or *neo* that for want of terminology. In creating a symbolic language to formalize the concepts of logic, Frege (1884) states "I found the inadequacy of language to be an obstacle." A century latter, a remarkably similar statement was made by Arms (1995): "Understanding of digital library concepts is hampered by terminology."

The words *information* and *knowledge* are used and misused in a broad range of contexts. *Webster's Ninth New Collegiate Dictionary* lists nine definitions for *information*, paraphrased below:

- Communication or reception of knowledge or intelligence.
- Knowledge obtained from investigation, study, or instruction (e.g., intelligence, news, facts, data).
- Attribute inherent in and communicated by alternative sequences or arrangements of something (e.g., nucleotides, binary digits) that produce specific effects.
- Signal or character (in a communication system or computer) representing data.
- Something (e.g., message, data, picture) which justifies change in a construct (e.g., plan or theory) that represents physical or mental experience or another construct.
- Quantitative measure of the content of information.
- Numerical quantity that measures the uncertainty in the outcome of an experiment.
- Act of informing against a person.
- Formal accusation of a crime made by a prosecuting officer

Webster's Dictionary also lists nine definitions for *knowledge* that are related to the present study:

- Fact or condition of knowing something gained through experience or association.
- Acquaintance with or understanding of a science, art, or technique.
- Fact or condition of being aware of something.
- Range of one's information or understanding.
- Circumstance or condition of apprehending truth or fact.
- Fact or condition of having information or being learned.
- Sum of what is known.
- Body of truth, information, and principles acquired by mankind.
- Branch of learning.

In essence, knowledge and information can be almost anything that anyone wants them to be. They are defined in terms of each other and are often used interchangeably. They are also defined through related terms (e.g., data, communication) for which we will need specific definitions. Small wonder that Toffler (1990) refers to the "alchemy of information."

This section describes a core set of terminology within five broad categories—content, processes, communication, the Internet, and the World Wide Web. A glossary follows that defines a broader set of terms that will be helpful for understanding knowledge managment.

Core Terminology

Knowledge Content

Knowledge content is the meaning that is being processed. Content has four forms, data (facts), information (what), knowledge (how), and wisdom (why), based on the level and amount of underlying processing. An analogy is that water has three forms, solid, liquid, and vapor, based on temperature. To simplify the discussion and reduce ambiguity, the term *content* will refer to all four forms collectively,

unless otherwise specified. Attributes of the four forms of content illustrate the differences among them.

Data: Recorded, ordered symbols (e.g., letters, numbers) that carry information. Data are the basic building blocks of information and knowledge. There are many types of data that can be categorized by form (digital, analog), purpose (thematic, spatial, temporal), processor (numeric, text), and media (documents, images, video, audio). Data are the least valuable form of content.

Information: Data that has been interpreted or translated to reveal the underlying meaning. For example, weather data can be processed to yield a fire-danger rating or letters can be interpreted as words, statements, and ideas. Ultimately, information is generally specific to a particular domain (activity, process, function). Information may be presented in many formats (reports, images, tables, charts) and media (documents, sound recordings, photographs, video). Information is more valuable than data.

Knowledge: Synthesized by combining diverse concepts and multiple information sources into a coherent whole, through inference or deductive reasoning. Knowledge may be oriented towards a domain-specific decision. For example, by combining fire danger, fire occurrence, values at risk, and resource status, an agency can dispatch the optimum combination of resources to each fire. Alternatively, knowledge may be oriented towards a policy issue. For example, by combining information on fire hazard, flood plains, soil stability, and socioeconomic values, a community can develop objective zoning regulations. Knowledge may be explicit (formally expressed) or tacit (gained through personal experience). Expert systems use both tacit and explicit knowledge that have been formally coded coupled with inference engines to diagnose difficult problems. Knowledge is more valuable than information.

Wisdom: The correct application of knowledge to select an alternative, based on an analysis of cause and effect, costs and benefits, and experience. Since the time of Francis Bacon (1561–1626), it has generally been held that knowledge is created to serve a purpose. Conversely, knowledge that is not used has little value. Thus, wisdom, or the use of knowledge, is the ultimate driver of the evolving knowledge-based economy. Wisdom is the most valuable form of content.

Knowledge Processes

Knowledge processes are functions and systems that add value to content by increasing the amount of underlying processing and consequent depth and breadth of meaning. Digitization, database management, information systems, and knowledge infrastructure are a sequence of processes that transform information from raw data into knowledge, much like machines along a production line. Characteristics of the four processes illustrate the differences among them.

Digitization: To electronically record data on a reproducible media. Digitization can be divided into two categories, ongoing activities and legacy collections. The former generally uses current technology, whereas the latter typically involves costly rescuing of obsolete data sources.

Database management: To enter, store, search, and retrieve data, and to organize data into files. Data management has traditionally been limited to domain-specific databases. Interoperability standards will be needed to enable cross-domain data sharing.

Information management: To acquire data, manage databases, interpret data, and produce output. Many CFS networks and programs have developed state-of-the-art domain-specific information and decision-support systems. However, use of this technology to manage information processes has not progressed much beyond administrative efficiency.

Knowledge management: To link multiple information systems, synthesize new knowledge, and manage knowledge assets.

Communication

Electronic communication is essential for knowledge management. The efficiency with which a message is moved from one place to another affects the effectiveness of a network. Electronic communication involves three processes, transmission, switching, and signal.

Transmission: The sending of an electronic signal from one point to another. It involves the national backbone, trunk lines that connect to the backbone, and distribution networks that connect to individual sites. A key element of transmission is bandwidth, the amount of data that can be carried at one time.

Switching: The routing of signals through a network towards their destinations. It may be synchronous (simultaneous transmission and receipt of a message, e.g., telephone) or asynchronous (non-simultaneous transmission and receipt of a message, e.g., e-mail). The latter may involve packet switching, which makes the Internet very cost-effective because it does not require a dedicated open line. It waits for openings in the communications stream

and sends small parts of large messages via different routes through a network, in the many unused spaces between messages.

Signal: The form in which data is transmitted. It may be analog (fluctuating current) or digital (binary). Telephone lines and cable networks that connect to individual homes use analog signals. Modems are needed to convert digital data to an analog signal for transmission via current networks and then reconverted to a digital format upon receipt.

Internet

The Internet is a system of cooperative global connectivity among communication networks, coupled with communication protocols that allow the networks to exchange digital information. It is essentially a network of networks that allows any site to connect to any other site in the world. The Internet is a transitional technology in the development of the Information Highway. Key elements of the Internet are services, protocols, and security.

Services: A wide range provided. The best known is e-mail, which allows individuals to asynchronously correspond with other individuals. Regrettably, it also allows spam (junk e-mail), which is becoming an increasing nuisance to Internet users. Another service is bulletin boards; these allow individuals to publicly post messages and other members of a discussion group to respond. Newsgroups are discussion groups composed of individuals with similar interests. Online chat groups permit nearly synchronous communication within a group, although they can be chaotic. Internet paging is expected to become popular by permitting simultaneous one-on-one exchanges.

Protocols: A set of rules or parameters that allow networks to exchange digital information. A variety exists for different services and include

- Gopher—document retrieval protocol; efficient, text-based, menu-driven file access.
- File Transfer Protocol (FTP)—transfers any file as a binary string; both sender and recipient must use the same software to process the file.
- Transmission Control Protocol/Internet Protocol (TCP/IP)—the primary Internet protocol.
- Telnet, Serial Line Internet Protocol (SLIP), and Point-to-Point Protocol (PPP)—connect to an Internet server via a modem.
- Network News Transfer Protocol (NNTP)—newsgroups.
- Internet Relay Chat (IRC)—chat groups.
- WAVE—broadband access via cable network.

Security: Procedures or methods to prevent unauthorized access to computer networks and individual PCs connected to the Internet. "Firewalls"offer some protection. Unauthorized access may also involve the introduction of viruses. These are hidden malevolent algorithms that, when activated, can cause serious damage to a computer or a network. Virus detection software has become essential to minimize the risk of damage. Security of personal information on the Internet is another issue. Many Web sites use registration, surveys, or cookies (software stored on a user's PC) to accumulate information about people who use their sites with no legal restrictions on how the collected information may be used. Doing business on the Internet can be risky but will become more sophisticated as synchronous or public key encryption is refined.

World Wide Web

The World Wide Web is a powerful global system of protocols and standards that enable the exchange of multimedia content. The Web permits anyone to inexpensively publish digital text, sound, and images and distribute them to a global audience. Conversely, it allows anyone to find, access, retrieve, and display or play anything that has been published on the Web. Key elements of the Web are publishing, hyperlinks, browsing, and tools.

Publishing: The creation of a digital document using HyperText Markup Language (HTML) and its storage on a Web site. This is usually accomplished with an HTML editor. The document may contain text, images, sound, or audio or any combination of media. It may also contain embedded hyperlinks, "hot spots," and feedback forms.

Hyperlinks: Access and retrieve HTML documents stored at any Web site in the world by means of HyperText Transfer Protocol (HTTP). This requires a Uniform Resource Locator (URL), a unique global document address, which is managed by the Domain Name System. Systems such as robots and spiders automatically search the Web for URLs and create lists and databases of active hyperlinks.

Browsing: The use of software to navigate around the Web to find, retrieve, and display HTML documents. The process is activated by clicking a mouse positioned on a URL that may be displayed directly, or that may underlie a "hot spot" embedded in text or an image. Browsers also enable user responses via e-mail links or feedback forms.

Tools: Facilitate and enhance the use of the Web. Editors assist in developing HTML pages; other software can check a site for errors (such as broken links). A variety of commercial search engines (Lycos, Alta Vista, Yahoo) search the Web by subject; they provide lists of active hyperlinks to related sites as well as supplementary information. It is possible to download an entire Web site for local viewing. It is also possible to evaluate how a site is ranked and indexed by major search programs.

Glossary

It is the man determines what is said, not the words.

—Henry David Thoreau (1817–1862)

This glossary defines a set of terms related to knowledge management. Although neither exhaustive nor definitive, the definitions are useful for developing a common understanding of the subject, an essential precursor to discussion. Each term is restricted to a single meaning relevant to knowledge management. Directions to related, sequential, or contrasting terms are also provided.

acquisition: accessing one or more remote sites and retrieving digital content; *see also* dissemination.

add-ons: viewers, players, and other multimedia additions to Web client software.

agent: a system that searches for available information and filters incoming information based on specified characteristics; *see also* knowbot.

AI: artificial intelligence.

algorithm: a set of instructions that tell a computer how to perform a specific task; *see also* model, computer program.

analog data: data that are represented by continuously variable physical quantities, such as electrical signal strength; *see also* digital data.

artificial intelligence (AI): the use of computer algorithms, models, and systems to emulate human perception, cognition, and reasoning; *see also* competitive intelligence, expert system, intelligence.

asynchronous: the transmission and receipt of a message do not occur simultaneously; thus this does not require a dedicated link between two points; *see also* synchronous.

Asynchronous Transfer Mode (ATM): technology that divides digital streams into packets of 48 bytes with 5 associated control bytes, moves each packet through the Internet towards its final destination, and reassembles the original digital stream.

ATM: Asynchronous Transfer Mode.

audio data: data that can be interpreted by audio processors to yield spoken language, music, or meaningful sounds; *see also* graphic data, numeric data, text data.

autonomous database: a database comprising data sets that are independently controlled and managed; *see also* distributed database.

b: bit.

B: byte.

backbone: the primary national transmission system; *see also* CANARIE, trunk line.

bandwidth: the amount of information that can be moved through a circuit in one second; *see also* baud.

baud: a unit of measure for communication speed; equivalent to the number of bits transmitted per second.

binary number: a number that can only have values of 1 and 0 (on and off); *see also* digital data.

bit: a single binary number with a value of 0 or 1.

browse: a search for content on the Web; *see also* browser.

browser: a popular term for client, a system that is designed to view and navigate hypertext; *see also* client.

bps or b/s: bits per second.

bulletin board: an electronic public forum created with software that supports multiple simultaneous callers, where participants can post and comment on messages from other participants.

byte: a group of eight bits that can code 256 different characters.

CANARIE: Canadian Network for the Advancement of Research, Industry and Education—the Canadian backbone.

chat: an online group discussion via simultaneous keyboard input; *see also* Internet Relay Chat.

Chief Information Officer: the senior executive responsible for information management and information technology at the corporate level.

Chief Knowledge Officer: the senior executive responsible for knowledge management and the knowledge infrastructure at the corporate level.

clickable map: *see* **image map.**

client: a system that allows users to access and browse the World Wide Web and display HTML pages.

client server: the system software that links a client to the system.

communication: the electronic transmission of content from one point to another; *see also* Information Highway.

competitive intelligence: internal data, information, and knowledge about one organization acquired by another for competitive purposes; *see also* artificial intelligence, intelligence.

computer program: precise, unambiguous, and detailed instructions on how to complete a task, written in a language that can be interpreted by a computer; *see also* algorithm, system.

content: *see* **knowledge content**

content value: the economic or social utility of data, information, knowledge, and wisdom.

cookie: a mechanism that enables a Web server to place a unique identifier file on a user's PC to store user registration and preference information, but the user has no control over how this information is used.

copyright: the right to copy; Canadian law grants copyright owners control over the use of their creations (or works prepared under their control) and an ability to benefit, economically and otherwise, from the exploitation of their works; *see also* intellectual property.

cyberspace: the collective global entity comprising all networks, computers, and communications lines where existence is virtual, in the form of electronic bits; *see also* matrix.

data: recorded, ordered symbols that carry information.

data acquisition: accessing one or more general databases and transferring data into a problem-specific database; *see also* data extraction, download.

database: a group of related data sets comprising data that is independent of applications, involves complex data relationships, and is protected by data security; *see also* data warehouse.

database management: using systems to store and delete, organize, search, retrieve, and manage access to data in a database; *see also* information management, knowledge management.

data element: one measurement or observation of one attribute of a data source; *see also* data record.

data exploration: the preliminary search and analysis of a database to determine its potential information content.

data extraction: extracting a subset of a large data file; *see also* data acquisition, download.

data file: a group of related data records; *see also* data set.

data mining: searching, accessing, extracting and manipulating data in databases.

data preservation: archiving data and metadata into redundant permanent storage, ensuring data integrity, and maintaining compatibility with evolving technology.

data processing: using computer hardware and software to manipulate data and perform calculations.

data record: group of related data elements; *see also* data file.

data set: group of related data files; *see also* data base.

data source: physical objects, states of nature, or processes that can be quantitatively measured or qualitatively described in the form of data; *see also* data element.

data stream: ordered sequence of data as it is being electronically transmitted; *see also* digital stream.

data warehouse: interoperable group of databases, database management systems, and search engines that span multiple domains; *see also* horizontal integration.

deciphering: *see* **decryption**

decision-support system (DSS): a system that uses analytic tools and quantitative models to adapt information to specific decisions, produce reports, and answer queries; *see also* information system, management information system, executive information system, expert system, issue support.

decryption: decoding a digital object into the source language with a key.

digital data: data that is represented by an ordered sequence of binary numbers; *see also* analog data.

digital library: a collection of a very large number of digital objects, comprising all types of material and media, that are stored in distributed information repositories and accessed through national computer networks; *see also* data warehouse.

digital object: an ordered sequential set of bits, including a unique identifier and sufficient information to reconstitute the object; *see also* digital work.

Digital Simultaneous Voice and Data (DSVD): a technology that uses phone networks to significantly increase the speed of digital communication.

digital stream: an ordered sequence of bits as it is being transmitted; *see also* data stream.

digital work: a creative work comprising ordered symbols from a discrete set that are capable of collective interpretation or behavior when processed; *see also* digital object.

digitization: transforming data, information, knowledge, or physical objects from various media into digital objects.

distributed database: a database comprising data sets that are stored in separate locations but are accessible in a single search; *see also* autonomous database, data warehouse.

distribution: moving electronic signals from trunk lines to their final destination through a distribution network; *see also* dissemination, transmission.

dissemination: distributing digital content from a site to clients and stakeholders; *see also* acquisition.

document: an HTML object that appears in the main window of a Web client; *see also* page.

download: to electronically access content stored at a remote location and move it to a local site; *see also* data acquisition, retrieval.

domain: the sphere of influence of an activity or process.

Domain Name System (DNS): a system for identifying and locating every site on the World Wide Web.

drill down: to access increasingly detailed data or information, starting from a high level of a hierarchical database or information base.

DNS: Domain Name System.

DSS: decision-support system.

DSVD: Digital Simultaneous Voice and Data.

editor: a program that assists in authoring HTML documents.

education: gaining explicit knowledge through formal schooling; *see also* skill, experience.

EIS: executive information system.

electronic mail (e-mail): electronic document transmitted in asynchronous mode to an electronic mailbox.

enciphering: *see* **encryption**

encryption: encoding a digital object so that it cannot be read without a key; *see also* decryption, symmetrical encryption.

ES: expert system.

executive information system (EIS): an information system that provides corporate information, such as financial condition, market share, and organizational performance in graphic form, with drill-down capability for detail; *see also* decision-support system, expert system, management information system.

experience: gaining tacit knowledge by doing things and observing the consequences; *see also* education, skill.

expert: a person with a high level of combined education, experience, and skill; *see also* wisdom.

expert system (ES): an information system that uses codified tacit knowledge in a knowledge base and an

inference engine to solve problems that normally require significant human expertise; *see also* decision-support system, management information system.

explicit knowledge: knowledge that has been formally expressed and transferred; *see also* tacit knowledge.

firewall: a security system that protects internal areas of a computer network from external access.

File Transfer Protocol (FTP): a communication standard for exchanging files through the Internet.

filter: a program that accepts or rejects incoming e-mail or other information based on specified sender names, sites, or subject.

form: part of an HTML document that accepts input from users. It can be used for feedback, or ordering products and services.

G: giga-; this prefix is often decimal, 1 billion (10^9), when referring to data transmission, and binary, 1 073 741 824 (2^{30}), when referring to data storage.

gateway: a server that links multiple networks and that translates different network communication protocols, enabling them to exchange messages.

GB: gigabyte.

geospatial data: spatial data that is registered to a specific point on the earth's surface.

gigabyte (GB): 1024 megabytes.

Gopher: a communications protocol for finding and accessing text information through the Internet with a menu interface.

graphical user interface (GUI): the use of graphical objects (icons) on a computer screen instead of characters on a keyboard to communicate with a computer, usually involving a mouse.

graphic data: data that can be interpreted by graphic processors to yield visual images, animation, or video sequences; *see also* audio data, numeric data, text data.

GUI: graphical user interface.

home page: the designated primary entry point for a local Web site.

horizontal integration: processing content (data, information, knowledge) from multiple domains in an integrated system; *see also* knowledge infrastructure, vertical integration.

hot spot: a hypertext region, within an HTML document that, when selected, links the user to the URL associated with the region.

HTML: HyperText Markup Language.

HTTP: HyperText Transfer Protocol.

hyperlink: a Web protocol that enables access and retrieval of HTML documents at any site by clicking on an active URL.

hypermedia: a Web protocol that enables access and retrieval of sound, graphics, and video.

HyperText Markup Language (HTML): coding standard for creating documents that can be displayed by a Web browser.

HyperText Transfer Protocol (HTTP): the primary communications standard used by the World Wide Web to access and transmit documents between sites.

IM: information management.

image map: a graphic map with two or more embedded hyperlinks that are accessed by clicking a mouse when the pointer is positioned over a portion of the map; also known as a clickable map.

inference engine: rule-based algorithms that interact with a knowledge base to draw conclusions about a set of inputs; *see also* expert system.

information: data that has been interpreted, translated, or transformed to reveal the underlying meaning; *see also* data, knowledge.

information appliance: an interface that enables users to send and receive digital objects (e.g., data, text, voice, graphic, movies) via the Information Highway.

information asset: information viewed as property; a commodity or product with associated costs and value; *see also* knowledge asset.

information base: database containing information (e.g. reports, documents, interpreted data); *see also* information repository, knowledge base.

Information Highway: the infrastructure that will enable cost-efficient digital transmission of and access to all forms of content and media through a single information appliance.

information management (IM): integrating information standards, processes, systems, and technology to enable the exchange of information among providers and users in order to support the management objectives of an organization; *see also* database management, knowledge management.

information overload: excess information beyond that desired or needed by a user that requires nonproductive processing.

information repository: an electronic database that contains documents or other digital objects; *see also* digital library.

information retrieval: finding, accessing, and downloading digital information through networks.

information revolution: the global-scale transformation from an industrial society to an information society; *see also* knowledge revolution.

information science: pure and applied science involving the collection, organization, and management of information; *see also* information theory.

information society: a society in which people interact with technology as an important part of life and social organization to exchange information on a global scale; *see also* knowledge-based economy.

information system (IS): a system that acquires digital content, increases the value of the digital content, and produces easily understandable reports; *see also* database management, decision-support system, executive information system, expert system, management information system.

information technology (IT): computer communications, networks, and information systems that enable exchanges of digital objects.

information theory: a statistical theory that measures information content and the efficiency of human–machine communication processes.

information worker: a person who uses information to accomplish work; *see also* knowledge worker.

Integrated Services Digital Network (ISDN): a technology that greatly increases digital data transmission speeds via phone networks by eliminating the need for analog to digital conversion; *see also* Digital Simultaneous Voice and Data.

intellectual property: refers to the intangible or intellectual nature of works or creations and the body of laws governing such property; there are six areas of intellectual property: patents, trademarks, industrial designs, confidential information, copyright, and integrated circuit topography protection.

intelligence: an ability to learn and understand new knowledge or reason in new situations; *see also* artificial intelligence, competitive intelligence.

interface: an input and display system that enables a person to interact with a computer; *see also* information appliance.

Internet: cooperative global connectivity among communication networks and communication protocols that allow the networks to exchange digital content; *see also* World Wide Web.

Internet paging: a program that detects when selected individuals sign on and off the Internet and supports online one-on-one discussions or group conferences.

Internet Relay Chat (IRC): a service that supports simultaneous keyboard input (discussion) among groups of people with similar interests.

Internet service provider (ISP): a company that provides access to the Internet.

interoperability: the ability of multiple databases to share digital objects across domains; *see also* horizontal integration, metadata.

interoperability standards: common metadata, file organization, and data formats that enable interoperability.

Intranet: Local Area Network (LAN) that uses Internet technology to exchange information.

IRC: Internet Relay Chat.

IS: information system.

ISDN: Integrated Services Digital Network.

ISP: Internet service provider.

issue support: using systematic methods to analyze information involving primarily subjective reasoning, in relation to complex issues; *see also* decision-support system.

IT: information technology.

k or K: kilo-; this prefix is often decimal, 1000 (10^3), when referring to data transmission, e.g. 56 kbps, and binary, 1024 (2^{10}), when referring to data storage, e.g. 50 KB

KB: kilobyte.

kb: kilobit.

kbs or kb/s: kilobits per second.

Key: encryption or decryption algorithm; *see also* public key, private key.

K-If: knowledge infrastructure.

K-It: knowledge initiative.

kilobit (kb): 1000 bits.

kilobyte (KB): 1024 bytes.

KM: knowledge management.

knowbot: a program that searches a network for information according to selected parameters; *see also* agent, robot, spider.

knowledge: information from multiple domains that has been synthesized, through inference or deduction, into meaning or understanding that was not previously known; *see also* information, wisdom.

knowledge acquisition: eliciting and formally coding tacit knowledge into facts and rules and entering them in a knowledge base; *see also* expert system, knowledge representation.

knowledge asset: knowledge viewed as property; a commodity or product with associated costs and values; *see also* intellectual property.

knowledge base: a database containing tacit knowledge in the form of formally coded facts and if-then-else decision rules; *see also* database, information base.

knowledge-based economy: an economy in which value is added to products primarily by increasing embedded knowledge content and in which the content value evolves to exceed the material value; *see also* information society.

knowledge content: the meaning that underlies data, information, knowledge, or wisdom; *see also* knowledge processes.

knowledge creation: use of reasoning to create new meaning or understanding; to know something that was not previously known; *see also* knowledge synthesis.

knowledge exchange: the electronic transfer of digital data, information, or knowledge between two or more parties.

knowledge infrastructure (K-If): an integrated architecture of computers, systems, networks, and communication technology that supports horizontally integrated and vertically integrated knowledge management.

knowledge initiative (K-It): building knowledge management capacity in terms of resources, knowledge infrastructure, and content and developing an organizational context to implement that capacity through leadership, culture, and learning.

knowledge integration: combining separate knowledge management programs into a more complete whole, coupled with adapting diverse groups into a coordinated knowledge-sharing culture.

knowledge management (KM): promoting, coordinating, and facilitating knowledge synthesis, preservation, processes, production and exchange in order to support the strategic goals of the organization; *see also* database management, information management.

knowledge object: a physical object used to support knowledge synthesis (e.g., a plant, insect, or rock collection).

knowledge preservation: implementing processes to capture, archive, and protect explicit and tacit knowledge and to maintain accessibility to it as technology evolves for as long as the knowledge remains useful.

knowledge processes: organizational context, human activities, content value, information systems, and information technology that are used to add value to content by increasing the amount of underlying processing and depth and breadth of meaning.

knowledge product: knowledge that has been adapted to the needs of specific users.

knowledge production: acquiring content, transforming it into a higher order of meaning and value, and disseminating it as knowledge products; *see also* knowledge synthesis.

knowledge representation: the framework and methods for coding tacit knowledge in a knowledge base; *see also* expert system, knowledge acquisition.

knowledge revolution: the global-scale transformation from an economy based on the value of material goods to one based on the value of knowledge; *see also* information society, information revolution, knowledge-based economy.

knowledge synthesis: using reasoning to integrate data and information from multiple domains to create a new meaning or understanding; *see also* knowledge creation, knowledge production.

knowledge worker: a person who creates information and knowledge; *see also* information worker.

LAN: Local Area Network.

Local Area Network (LAN): internal network within an organization; *see also* Intranet.

link: active Web reference to a document or another part of the same document; *see also* hyperlink.

M: mega-; this prefix is often decimal, 1 million (10^6), when referring to data transmission, and binary, 1 048 576 (2^{20}), when referring to data storage.

management information system (MIS): a system that provides mid-level information, such as budgets, project reports, and resource status with statistical, graphic, query, and report generation capabilities; *see also* decision-support system, executive information system, expert system, information system.

matrix: the global set of all networks that can exchange e-mail either directly or through gateways; the Internet is a subset of the matrix.

MB: megabyte.

Mb: megabit.

Mbps or Mb/s: megabits per second.

meg: informal for megabyte.

megabyte (MB): 1024 kilobytes.

metadata: data about data; a description of the attributes of a digital object that is sufficient to access and reconstitute the object but is independent of the object itself; *see also* interoperability, information repository.

model: simplified mental, physical, or mathematical representation of reality that enables increased understanding of observed phenomena; *see also* algorithm, system.

modem (modulator-demodulator): a device that converts a digital stream into an analog signal for transmission via telephone lines and reconverts an analog signal into a digital stream upon receipt, thereby allowing a computer to communicate with other computers over telephone lines.

multimedia: the capacity of a system and network to process and transmit text, data, sound, graphics, animation, etc.

navigation: using hyperlinks and URLs to move from one site to another through the Web to find and access documents; *see also* browsing, surfing.

network: communication connectivity among a group of nodes, sites, computers, workstations, people, organizations, etc.

Network News Transfer Protocol (NNTP): a communications standard used for exchanging Usenet news.

News Alert: a system that tracks breaking news stories.

newsgroup: a Usenet forum for distributed electronic discussion of a selected topic of mutual interest. Usenet functions throughout the matrix.

NNTP: Network News Transfer Protocol.

numeric data: data that can be processed with quantitative algorithms to yield mathematical outputs; *see also* graphic data, text data.

organizational learning: increasing collective skills, experience, and knowledge so that an organization can function more effectively in a dynamic environment.

packet: a subset of a complete message with associated identification and routing information; *see also* Asynchronous Transfer Mode.

page: individual HTML document that can be displayed by a Web browser.

player: a system-specific software capable of presenting audio or video files that are accessed through the Web; *see also* multimedia, viewer.

Point-to-Point Protocol (PPP): A communications convention that provides access to an Internet server via telephone line and modem; *see also* Serial Line Internet Protocol.

PPP: Point-to-Point Protocol.

private key: private component of an encryption–decryption key (e.g., two large prime numbers); *see also* public key.

protocol: a convention or standard governing the formatting of digital messages that permit communication among networks.

public key: public component of an encryption–decryption key (e.g., the cross-product of two large prime numbers); *see also* private key.

query: requesting information from a database, using keywords or plain text; *see also* database management, information system.

RAP: Repository Access Protocol.

real-time (adj): relating to a system in which the computer obtains data from a source, processes it, and applies the results to another process going on nearly simultaneously.

reasoning: the use of inference and deduction by people to create knowledge; *see also* knowledge synthesis.

record (n): *see* **data record.**

record (v): register permanently on a reproducible media; *see also* digitization.

report generator: a system that generates responses to queries provides automated status reports, or reports on the contents of a database; *see also* executive information system, information system, and management information system.

repository: a server for storing, managing, and retrieving digital objects; *see also* digital library.

Repository Access Protocol: a communications convention that links client servers to information repositories; *see also* digital library.

retrieval: to access electronic data or information stored in a database or repository and transfer it to another site; *see also* data acquisition, download.

robot: a program that automatically searches the Web for URL addresses and creates HTML documents that list the results; *see also* knowbot, spider.

routing: selecting the best route from a source to a destination through a network; *see also* switching.

search engine: a program that searches a data warehouse, information repository, network, or digital library in response to a query; *see also* information system, database managment.

Serial Line Internet Protocol (SLIP): a communication protocol that provides access to an Internet server via a telephone line and modem; *see also* Point to Point Protocol.

server: a computer that links to external communication networks and manages internal distribution networks.

signal: a detectable physical quantity or impulse, such as voltage, current, or magnetic field strength, by which information is transmitted.

site: part of an organizational computer network that stores HTML documents and is accessible through the Web.

skill: the combination of knowledge and physical ability to perform tasks; *see also* education, experience.

spam: unsolicited, automated, mass-distributed e-mail; junk e-mail; an increasing nuisance to Internet users and service providers.

spatial data: data with a primary file structure of spatial coordinates intended to analyze and display spatial patterns; *see also* temporal data, thematic data.

spatial navigation: navigating through virtual two- or three-dimensional space by clicking on images to indicate choices.

spider: a program that automatically searches the Web for URL addresses and creates an HTML database of active hyperlinks; *see also* knowbot, robot.

surfing: using hyperlinks and URLs to scan the Web for potentially useful or interesting content; *see also* browsing, navigating.

switching: connecting communication lines according to routing instructions to transmit information to a sequential destination in a network.

symmetrical encryption: both the sender and recipient use identical software to encrypt and decrypt a message by means of a password.

synchronous: the transmission and receipt of a message occur simultaneously; this requires a dedicated link between two points for the duration of the message; *see also* asynchronous.

system: set of integrated components that function collectively to transform inputs into outputs to achieve a common goal; *see also* model, information system.

T: tera-; this prefix is often decimal, 1 trillion (10^{12}), when referring to data transmission, and binary, 1 099 511 627 776 (2^{40}), when referring to data storage.

tacit knowledge: personal knowledge, gained through experience, that is influenced by beliefs, perspectives, and values; *see also* explicit knowledge.

TCP/IP: Transmission Control Protocol/Internet Protocol.

Telnet: a means of remotely logging onto a host computer via telephone.

temporal data: data with a primary file structure of temporal coordinates intended to analyze and display time series; *see also* thematic data, spatial data.

text data: data that can be interpreted by word processors to yield written language; *see also* audio data, graphic data, numeric data.

thematic data: data with a primary file structure of subject-matter classification intended to analyze and display processes; *see also* temporal data, spatial data.

transmission: moving an electronic signal along trunk lines and the backbone between distribution networks; *see also* communication.

Transmission Control Protocol/Internet Protocol (TCP/IP): set of conventions for formatting messages that gateway servers use to connect to the Internet; *see also* Point to Point Protocol, Serial Line Internet Protocol.

trunk line: primary line connecting distribution networks to the national backbone.

Uniform Resource Locator (URL): unique global address for every page on the Web.

URL: Uniform Resource Locator.

Usenet: a worldwide bulletin board system for sharing asynchronous text discussion among a group of sites; contains more than 15 000 newsgroups or forums.

value: *see* **content value**.

viewer: a program that can display graphics or video files accessed through the Web; *see also* player.

vertical integration: processing domain-specific content from raw data through information to knowledge in an integrated system; *see also* horizontal integration, decision-support system.

virus: an algorithm, usually hidden in a benign-looking e-mail message or a computer file that, when activated or self-activated, causes inconvenience or serious damage to a computer system or network; many are self-replicating and self-transmitting from one machine to another.

virus protection: software that monitors incoming messages and files and searches existing files to detect viruses, monitors computers and networks for virus-like activity, notifies the operator, and removes the virus.

WAVE: high-speed Internet connectivity via cable network.

Web: the short form of World Wide Web.

Web log analysis: systems that analyze the effectiveness of a Web site by tabulating and reporting on how the site is used.

wisdom: correct application of knowledge.

World Wide Web: a globally distributed hypermedia system that supports publication and global dissemination of multimedia digital works as well as global searching, accessing, retrieving, and displaying or playing published works; *see also* Internet.

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